AMERICAN SOCIETY
FOR
TESTING MATERIALS.
and

AFFILIATED WITH THE
INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

PROCEEDINGS

OF THE

EIGHTH ANNUAL MEETING

Held at Atlantic City, New Jersey,
June 29, 30, July 1, 1905.

VOLUME V.

EDITED BY THE SECRETARY, UNDER THE DIRECTION OF THE COMMITTEE ON PUBLICATIONS.

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Atlantic City, N. J., June 29, July 1, 1905.

The Eighth Annual Meeting of the American Society for Testing Materials was held at the Hotel Chalfonte, Atlantic City, N. J., on June 29–July 1, 1905. The total attendance at the meeting, including guests, was over 200.

The following members were present or represented at the meeting: W. A. Aiken; Ajax Metal Company, represented by G. H. Clamer; American Bridge Company, represented by C. C. Schneider; American Foundrymen's Association, represented by Richard Moldenke; Ira O. Baker; James A. Beckett; Bethlehem Steel Company, represented by E. O'C. Acker; John Birkinbine; Joseph C. Blanch; A. Bonzano; Cyrus Borgner; W. A. Bostwick; W. H. Boughton; John G. Brown; Samuel A. Brown; W. L. Brown; Jacob Cambier; Cambria Steel Company, represented by Clinton R. Stewart; H. H. Campbell; William Campbell; John A. Capp; Carnegie Steel Company, represented by W. A. Bostwick; Carpenter Steel Company, represented by George W. Sargent; Central Iron and Coal Company, represented by J. Lodge; Frank P. Cheesman; James Christie; Charles H. Clifton; Albert Ladd Colby; J. Allen Colby; E. A. Condit, Jr.; P. H. Conradson; H. C. Crawford; Robert A. Cummings; Allerton S. Cushman; Nathan H. Davis; William M. Davis; Cyril De Wyrall; R. D. DeWolf; H. E. Diller; Joseph Dixon Crucible Company, represented by Malcolm McNaughton; A. W. Dow; W. C. DuComb, Jr.; Charles B. Dudley; W. O. Dunbar; M. Ward Easby; Daniel W. Edgerly; Theodore H. Ellis; *Engineering Record*, represented by John M. Goodell; S. M. Evans; W. W. Ewing; Henry Fay; C. N. Forrest; William Forsyth; Adam H. Fox; Lawford H. Fry; H. S. Goodwin; William F. M. Goss; Herbert T. Grantham; Russel S. Greenman; William L. Hall;

Arthur B. Harrison; William K. Hatt; G. B. Heckel; George P. Hemstreet; Joseph A. Holmes; A. P. Hume; Richard L. Humphrey; John Andrew Hunter; Charles L. Huston; A. Lincoln Hyde; Illinois Steel Company, represented by P. E. Carhart; International Acheson Graphite Company, represented by A. M. Collins and E. C. Sprague; *Iron Trade Review*, represented by A. Van Zwaluwenburg; John M. Jeffers; Frederick E. Jenkins; Robert Job; Arthur N. Johnson; Lewis J. Johnson; W. Martin Johnson; C. R. Jones; Edgar B. Kay; Frank G. Kennedy, Jr.; E. F. Kenney; William Kent; J. A. Kinkead; Paul Kreuzpointner; Gaetano Lanza; E. S. Larned; Robert W. Lesley; J. B. Lober; Lukens Iron and Steel Company, represented by Charles L. Huston; T. D. Lynch; J. W. McGrady; E. McLean; John McLeod; Charles Major; Edgar Marburg; John A. Mathews; Richard K. Mead; Mansfield Merriman; William Metcalf; Rudolph P. Miller; Charles M. Mills; Leon S. Moisseff; Richard Moldenke; National Tube Company, represented by Frank N. Speller; F. H. Neff; E. D. Nelson; George L. Norris; Logan Waller Page; The Pennsylvania Steel Company, represented by H. H. Campbell; George E. Perley; J. Howard Pew; W. A. Polk; James Madison Porter; J. W. Prince; H. H. Quimby; *Railroad Gazette*, represented by R. C. Davison; J. C. Ramage; Louis E. Reber; C. S. Reeve; Clifford Richardson; Joseph Royal; A. H. Sabin; L. C. Sabin; Albert Sauveur; F. E. Schmitt; C. C. Schneider; Harry J. Seaman; Jesse J. Shuman; H. E. Smith; J. P. Snow; Henry S. Spackman Engineering Company, represented by E. W. Lazell; F. P. Spalding; C. R. Spare; Standard Steel Works, represented by George L. Norris; F. M. Stapleton; Clinton R. Stewart; P. M. Stewart; Bradley Stoughton; E. Stuetz; George F. Swain; Howard Taggart; Arthur N. Talbot; Henry P. Talbot; William Purves Taylor; Gustave W. Thompson; Sanford E. Thompson; Maximilian Toch; Enrique Touceda; N. B. Trist; F. E. Turneaure; C. P. Van Gundy; Herman von Schrenk; Joseph F. Walker; R. F. Walker; Leonard C. Wason; William R. Webster; Max H. Wickhorst; H. V. Wille; Paul L. Wolfel; Ira H. Woolson; Joseph R. Worcester; H. Winfield Wyman; Total number, 164 (including representations); total number in personal attendance, 155.

FIRST SESSION.—THURSDAY, JUNE 29, 3 P.M.

Business Meeting.

President Charles B. Dudley in the chair.

The minutes of the Seventh Annual Meeting were approved as printed.

The annual report of the Executive Committee and the report of the Auditing Committee were adopted as printed.

The following amendments of the By-Laws, proposed by the Executive Committee, were passed to letter-ballot:

Present By-Laws.

ARTICLE I.

SECTION 1. Any person, corporation or technical society holding membership in the International Association for Testing Materials is eligible for membership.

SEC. 2. Any person, corporation or society can become a member of this Society and of the International Association for Testing Materials simultaneously upon being proposed by two members of this Society and being approved by its Executive Committee.

SEC. 3. Any member who subscribes annually the sum of fifty dollars ($50) toward the general funds of the Society shall be designated a Contributing Member, his rights and privileges as a member remaining unchanged.

ARTICLE IV.

SECTION 2. The annual dues of each member shall be $5.00. Of this amount $1.50 shall be transmitted by the Secretary to the International Association for Testing Materials. The remainder shall be applied to the treasury of the Society.

Proposed Amended Form.

ARTICLE I.

SECTION 1. Any person, corporation or technical society can become a member of this Society upon being proposed by two members and being approved by the Executive Committee.

SEC. 2. Any member who subscribes annually the sum of fifty dollars ($50) towards the general funds of the Society shall be designated a contributing member, his rights and privileges as a member remaining unchanged. Contributing members shall be exempt from the regular membership dues.

ARTICLE IV.

SECTION 2. The annual dues of each member shall be $5.00. Members holding membership also in the International Association for Testing Materials shall pay annually the additional sum of $1.50, which shall be transmitted by the Secretary to the International Association.

It was resolved that the Society shall retain its membership as a body in the International Association for Testing Materials, and that a contribution of not less than $100.00 be made for the current year to the general funds of the Association.

The Chair appointed Mr. H. E. Diller, Mr. Richard L. Humphrey, and Mr. Edgar B. Kay as tellers to canvass the ballot for officers.

The annual reports of the following standing committees were read, discussed and referred to publication:

Committee K, on Standard Methods of Testing. Gaetano Lanza, Chairman.

Committee O, on Uniform Speed in Commercial Testing. Paul Kreuzpointner, Chairman.

Committee P, on Fire-proofing Materials. Ira H. Woolson, Chairman.

Committee Q, on Standard Specifications for the Grading of Structural Timber. Herman von Schrenk, Chairman.

The tellers reported that 109 legal ballots had been cast for officers and in accordance with their report the Chair declared the election of Mr. W. A. Bostwick and Mr. John McLeod as members of the Executive Committee.

The meeting then adjourned till 8 P.M.

SECOND SESSION.—THURSDAY, JUNE 29, 8 P.M.

Joint Meeting with the Society for The Promotion of Engineering Education.

President Charles B. Dudley of the American Society for Testing Materials, and President F. W. McNair of the Society for The Promotion of Engineering Education, presided jointly at this session.

President Dudley read the Annual Presidential Address on "The Testing Engineer."

The following papers were then read and discussed:

"A Course of Laboratory Instruction in Testing Materials." W. K. Hatt.

"A Course in Properties of Materials." G. L. Christensen.

"Plan and Scope of the Proposed Investigation of Structural

Materials Under the Auspices of the U. S. Geological Survey." J. A. Holmes and Richard L. Humphrey.

The meeting then adjourned till the following morning.

THIRD SESSION.—FRIDAY, JUNE 30, 10 A.M.

Section on Preservative Coatings.

President Charles B. Dudley in the chair.

The annual reports of the following Standing Committees were read and accepted:

Committee E, on Preservative Coatings for Iron and Steel. S. S. Voorhees, Chairman.

Committee N, on Standard Tests for Lubricants, W. M. Davis, Chairman.

Mr. G. W. Thompson read a paper on "Proper Methods of Conducting Painting Tests," which was discussed jointly with the report of Committee E.

A Topical Discussion on the subject of "Standard Specifications for Preservative Coatings for Steel," was introduced by Messrs. Charles B. Dudley, Maximilian Toch and Cyril de Wyrall.

Mr. Louis H. Barker presented a paper on "Protection of Iron and Steel Structures by Means of Paper and Paint."

The session was closed with a Topical Discussion on "What is the Best Method of Painting Steel Cars?" introduced by Messrs. F. P. Cheesman, G. W. Thompson and S. M. Evans.

The meeting then adjourned till 3 P.M.

Section on Cement.

Vice-President Robert W. Lesley in the chair.

The annual reports of the following standing committees were read and accepted:

Committee C, on Standard Specifications for Cement. George F. Swain, Chairman.

Committee I, on Reinforced Concrete. F. E. Turneaure, Chairman.

Mr. Richard L. Humphrey gave a description, illustrated by lantern slides, of "The Collective Portland Cement Exhibit and the Results of the Tests Made at the World's Fair, St. Louis, Mo."

The following papers were then read and discussed:

"Normal Consistency Tests of Neat Cement." Topical Discussion, introduced by R. S. Greenman.

"Economical Mold for Forming Compressive Test Pieces for Concrete." Clifford Richardson and C. N. Forrest.

"Slow-pulling, Early-stage Rotary Portland Cement vs. the Ordinary Early-strength-developing Product. W. A. Aiken.

"Impact Tests of Asphalt Paving Mixtures." Clifford Richardson and C. N. Forrest.

"Investigation of the Effect of Heat Upon the Crushing Strength and Elastic Properties of Concrete." Ira H. Woolson.

"British Standard Specifications for Cement," with introduction by R. W. Lesley.

The meeting then adjourned till 3 P.M.

FOURTH SESSION.—FRIDAY, JUNE 30, 3 P.M.

President Charles B. Dudley in the chair.

Committee A on Standard Specifications for Iron and Steel, W. R. Webster, Chairman, presented a report on the proposed revised Standard Specifications for:

(*a*) Structural Steel for Bridges.
(*b*) Steel Rails.
(*c*) Steel Castings.
(*d*) Steel Axels.
(*e*) Steel Forgings.

These specifications were considered separately and the following action resulted:

Proposed Standard Specifications for Structural Steel for Bridges: Amended and passed to letter-ballot

Proposed Standard Specifications for Steel Rails: Amended and referred back in part to Committee A with power; these specifications to be referred to letter-ballot of the Society after action on the part of the Committee.

The consideration of the proposed Standard Specifications for Steel Castings, Steel Axles and Steel Forgings, was on motion deferred till the next session.

Then followed the presentation and discussion of a paper by Mr. Robert Job on "Some Causes of Failure of Rails in Service."

On motion of Mr. A. W. Dow it was resolved, that the Executive Committee be instructed to consider the appointment of a Committee on Waterproofing Materials.

Mr. Mansfield Merriman moved that the question of appointing a committee on "The Formulation of a Plan for Making Such Scientific Tests of Structural Steel as Seem Likely to be of Advantage to the Engineering Profession," be referred to the Executive Committee with power. This motion was carried.

The Secretary moved that a committee be appointed to draft a Memorial Minute on the death of Professor Ludwig von Tetmajer, President of the International Association for Testing Materials, and that President Dudley be invited to accept the Chairmanship of that committee. The Chair accordingly announced the appointment of Mr. Mansfield Merriman and Mr. Gaetano Lanza as additional members on that committee.

The meeting then adjourned till the following morning.

FIFTH SESSION.—SATURDAY, JULY 1, 10 A.M.

President Charles B. Dudley in the chair.

The proposed Standard Specifications for Steel Castings, Steel Axles and Steel Forgings, proposed by Committee A, were on motion referred to letter-ballot.

The annual report of Committee M on Standard Specifications for Staybolts, was presented by Mr. H. V. Wille, Chairman, and referred to publication.

Then followed the presentation and discussion of a paper by Mr. H. V. Wille on "Influence of Methods of Piling Staybolt Iron on Vibratory Tests."

In the absence of the author, Mr. W. K. Hatt read "A Preliminary Report on the Effect of Combined Stresses on the Elastic Properties of Steel," by Mr. E. L. Hancock.

The annual report of Committee B on Standard Specifications for Cast Iron and Finished Castings, Walter Wood, Chairman, was presented, embodying, 1. Proposed Standard Specifications for Car Wheels, and 2. Proposed Standard Specifications for Gray Iron Castings.

The proposed Standard Specifications for Car Wheels were referred to letter-ballot without amendment.

The proposed Standard Specifications for Gray Iron Castings were slightly amended and referred to the Committee with power; these specifications to be referred to letter-ballot of the Society after action on the part of committee.

The following papers were then read and discussed:

"A Comparison of Standard Methods of Testing Cast Iron." Richard Moldenke.

"Hard Cast Iron: The Theory of One of its Causes." Henry Souther.

"Some Laboratory Records of Pig Iron Analysis with Notes." Lambden Buel.

"The Thermit Process in American Practice." E. Stuetz.

On motion of Mr. James Christie it was resolved, that the Executive Committee be instructed to consider the question of providing temporary headquarters for the Society, and given power to act.

The following Memorial Minute on the death of Professor Ludwig von Tetmajer, President of the International Association for Testing Materials, was adopted:

"The American Society for Testing Materials, assembled in its Eighth Annual Meeting, desires to express its deep sense of the loss which the engineering profession has sustained in the death of Ludwig von Tetmajer, President of the International Association for Testing Materials.

"The labors of von Tetmajer in establishing and developing the testing laboratory at Zurich furnished a stimulus for similar work throughout the world. His investigations in formulating precise and uniform methods of testing, and in coordinating theory and practice, have been valuable and fruitful. The results of his experimental work will long continue to be models of painstaking and precise investigation into the properties of materials in the directions both of scientific research and industrial development. The plans for unifying methods of testing, so well begun by Bauschinger from 1884 to 1893, were continued by von Tetmajer, and through his initiative The International Association for Testing Materials was organized in 1895. As President of this Association from 1895 until his untimely death on January 31st, 1905, he extended its influence to all civilized countries, where his loss is now sincerely mourned. The field of engineering in which he

so effectively labored will long continue to be inspired by his scientific spirit and his successful achievements.

"*Resolved*: That the above Minute be published in our Proceedings and that copies of the same be sent to the bereaved family of von Tetmajer and to the Council of the International Association for Testing Materials."

The meeting then adjourned till 3 P.M.

SIXTH SESSION.—SATURDAY, JULY 1, 3 P.M.

President Charles B. Dudley in the chair.

The annual reports of Committee G on the Magnetic Testing of Iron and Steel, J. Walter Esterline, Chairman, was, in the absence of the Chairman, read by title.

The annual reports of the following committees were read and accepted:

Committee H, on Standard Tests of Road Materials. L. W. Page, Chairman.

Committee R, on Boilers. E. D. Meier, Chairman *pro tem.*

On motion the recommendation of Committee R, "that the Executive Committee be Instructed to Cooperate With the American Boiler Manufacturers Association and the Association of American Steel Manufacturers in Urging and Formulating a Plan for the Improvement of the U. S. Steamboat Inspection Service in Relation to Boilers and their Appurtenances," was approved.

The following papers were then read and discussed:

"Specifications for Cotton Tapes for Electrical Purposes." R. D. DeWolf.

"A Large Hydraulic Testing Machine for Uniform Loads." Robert A. Cummings.

A paper by Mr. P. H. Dudley on "Rail Sections as Engineering Structures" was, in the absence of the author, read by title.

On motion of Mr. J. A. Kinkead it was resolved, that the Executive Committee be instructed to consider the appointment of a committee on "The Tempering and Testing of Steel Springs."

On motion of the Secretary the meeting passed a vote of thanks to the Management of the Steel Pier for its courtesy in placing the pier at the disposal of the Society during the meeting.

The President thereupon declared the meeting adjourned *sine die.*

AMERICAN SOCIETY FOR TESTING MATERIALS.

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PROCEEDINGS.

THE TESTING ENGINEER.

ANNUAL ADDRESS BY THE PRESIDENT, CHARLES B. DUDLEY.

The gradual widening of the scope of the word "Engineer" is very interesting. Used apparently as long ago as the time of William the Conqueror, to designate men who had the ability to design and construct works of value, such as castles, or fortifications, or bridges, especially in connection with military affairs, it soon took on a wider meaning, and was properly applied to men having ability to design and construct works of practical utility in times of peace. The military men having simply been called "engineers," it became desirable to designate those who were doing similar work during peace times, in some way to distinguish them and accordingly in contradistinction from the military engineers, they were called "Civil Engineers," a designation which remains up to the present, and characterizes some of the ablest men of the time. It would hardly be possible, or perhaps worth our while, to attempt to follow up historically the successive developments of this word "engineer." Suffice it to say that as time progressed, those who were able to design and construct something of value in the realm of mechanics, or other fields of human effort, were called "Mechanical Engineers," "Mining Engineers," "Naval Engineers," "Electrical Engineers," or, indeed, "Chemical Engineers." It is worth while to notice also, that as time

has progressed, the meaning of the word, as well as its application, has broadened. Primarily applied apparently to one who had genius born in him, and therefore who had within himself the power to originate and to execute, in course of time, we find the term applied to those also who simply direct, or carry to successful conclusion something they may have taken in hand. Indeed at the present time, the one who controls the machinery of a ship, as well as the one who handles the throttle of a locomotive, is called an "engineer." And, finally, it is apparently no abuse of words to say of a man who has guided any scheme in which he was interested, with ingenuity and tact, or overcome obstacles by contrivances and effort, that he has successfully engineered his project through. In view of these thoughts, we are perhaps justified in regarding the man engaged in testing as an engineer, and not only in choosing "The Testing Engineer" for our title, but also in discussing in some of his relations, that man who, if we read the signs of the times rightly, is becoming every day more and more prominent in the industrial world, and, as time progresses, is destined to play continually, a more and more important part in the development of our civilization.

The field which the Testing Engineer occupies, and the cause to which his loyalty is due, may perhaps wisely claim a few moments, attention. It is plain that the Testing Engineer acts in a threefold capacity. He is either an investigator, or a counsellor, or a judge. He is finding out new truths, he is protecting the interests of his client the producer, or he is determining by his tests that contracts are being fulfilled, or specifications lived up to, in the interests of his client the consumer. While all three forms of the Testing Engineer may be and often are engaged in research, in investigating a knotty problem, or devising means of demonstrating a point, it is perhaps more commonly the work of what may be called the "unattached Testing Engineer" to make investigations. The professors in colleges, especially those having a genius for experiment, and indeed independent investigators, who, as the result of business shrewdness or by good fortune, are so situated that they are not compelled to struggle for an existence, are continually adding to the sum of human knowledge by their tests and experiments while laboring in this field. They have no clients to satisfy, no employer's interests to defend, and no antagonisms

to overcome, except perchance the unwillingness of nature to yield up her secrets. Their loyalty is to the truth alone; their stimulus, their zeal for knowledge, and their reward, the approbation of their fellows. These seem to be almost ideal conditions for securing the truth, and it would seem as though results obtained by such experimenters, or Testing Engineers, and under such conditions, ought to be accepted and acted on without question. But we venture to suggest that there is one desirable, not to say essential element, in the search for truth, that is lacking in the conditions outlined above. This is the element of human antagonism. Perhaps an example will best make the point clear. The subject for investigation we will say is a method for determining phosphorus in steel. The professor, or independent investigator, makes his studies and experiments, and publishes his results. During the whole investigation he has been actuated by no desires, except to get at the truth. There has been no temptation, except perhaps the desire to finish the investigation, to stimulate him to neglect any essential point, to give any results or draw any conclusions that the most rigid interpretation of the facts would not warrant, and hence so far as accuracy is concerned, it would appear as though no questions should be raised. And yet, so great is our belief in the value of human antagonism, where the truth is involved, that we cannot help saying that we would prefer a method which resulted from the contentions of two chemists, the one of whom was the employee of a consumer and who was trying to make out that the sample on which they were both working contained more phosphorus than the specifications allowed; and the other of whom was the employee of the producer, and who was trying to show that the phosphorus in the sample was below the requirements of the specifications, there being a large commercial transaction involved in the result. We cannot help feeling that every point in the method would receive much more severe criticism, and consequently if it survived would be much more worthy of confidence under these conditions, than if it were brought out by a single experimenter making investigations for the sake of publishing them. So greatly does the legal fraternity rely on the element of human antagonism as an essential feature in the development of truth, that we are entirely safe in saying that the whole structure of legal procedure is based on this foundation.

It may not be amiss here also to quote from one of our instructors in chemistry, who had reached the philosophic age, and who in a very dry way used to say that during his active work he had tested many published methods in analytical chemistry, which, for some reason, not necessary to explain, always apparently gave better results in the hands of those who devised them than he was ever able to get from them. We fancy it hardly needs saying that in this matter there is no intention of questioning the integrity or reliability of investigators who are studying the truth for the truth's own sake. The point we had in mind was to suggest the thought that perhaps those who are accustomed to glorify pure science may have overlooked one fairly important element in the development of truth.

Returning to the Testing Engineer: As already indicated, the field of work of this important element in the industrial world seems to be either to find out new things, or to protect the interests of the producer or consumer. And there are three kinds of testing engineers to occupy these two fields, viz., the unattached engineer, the consumer's engineer and the producer's engineer. At first, there were apparently only two kinds of testing engineers, viz., the unattached and the consumer's. But it did not take long after consumers began to study and test materials and prepare specifications, before the producers found it necessary to protect their interests and defend their materials by means of testing engineers in their own employ.

It is perhaps hardly necessary to say that in this, our analysis of the scope and field of the Testing Engineer, we have not forgotten the various inspection bureaus and testing laboratories which are doing such excellent work in various parts of the country. As we understand the matter, these organizations, while perhaps not strictly covered by the definitions given, in that they do not derive their continuous sustenance in such a way as the unattached testing engineers, nor in the same way as those who defend the interests of the consumer or the producer, and in that they have an independent organization, and owe loyalty only where it is paid for; yet in a certain sense these independent organizations do perform exactly the same functions as the three classes of testing engineers which we have described. Any one of them will make investigations either in the interests of a client or for the sake

of the truth alone; any one of them will temporarily, or continuously, if the retainer be sufficient, defend and care for the interests of a consumer, or will render a like service for a producer, provided, of course, that the interests of the two are not antagonistic at the same time. So that we cannot help feeling that the three kinds of testing engineers mentioned, the unattached, the producer's and the consumer's, fairly well cover the field.

What now shall be the cast of mind, and what the mental equipment of the Testing Engineer? Upon the first of these topics, it is difficult to say much that is positive. It is perhaps easier to say what kind of mind will not succeed in this branch of engineering, than to say what the positive requirements of a successful testing engineer are. We will perhaps all agree that he should be independent, self-reliant, gifted with the power of analysis of facts, as well as with the power of drawing conclusions from the data at hand. He should be ingenious in devising methods to demonstrate the points at issue, and a careful observer of data. He must keep himself free from bias or prejudice, and take especial pains that he does not deceive himself. He should be fond of experiment and have a genius for it. Many times during our nearly thirty years attempt to do something in the line of the work of a testing engineer, we have had occasion to paraphrase the Latin apothegm and say, "experimenters are born, not made." He should keep constantly in mind the end to which his experiments tend, and understand clearly the effect of every step in the progress of his tests, and its influence on the final result. Above all, he should be a thinker. No man who, when a problem is presented to him, simply searches his memory for whatever he may have learned in the schools, or have perchance picked up in his reading, which bears on his problem, has any especial call to be a testing engineer. We are quite ready to allow that the power of seeing analogies between your own problem, and one that some one else has had, and perchance successfully solved, is a legitimate and useful, not to say time-saving habit of mind, but the point we want to make is that the one who habitually and continuously approaches every problem through memory, or by studying up what others have done, is far less likely to succeed as a testing engineer, than one who habitually attacks a problem by an analysis of its elements.

But it may be urged, if experimenters are born, not made, and if so much depends on cast and habit of mind, what can the schools do in the way of training and furnishing mental equipment to produce successful testing engineers? We answer much, every way. While it is probably not possible for any school to make a thinker out of a dreamer, or a successful experimenter out of a numskull, we still claim that, given ordinary fair mental endowment, it is possible for the schools to make successful testing engineers, or to spoil the material they start with.

It hardly comes within the sphere of this paper, or coincides with our present purpose, to say anything about the curriculum of studies best calculated to fit a man to be a successful testing engineer. This is neither the time nor the place for such a paper, although we may possibly say something a little later about the self-education of the one who expects to spend his energy in this field of work. At this place we will, however, touch upon one or two points in connection with methods of teaching. Our observation of what the world wants to-day, not only in the field and work of testing engineers, but also in almost every other field, is men who can think; men with minds so trained and so fitted with mental equipment, that when unexpectedly and for the first time put in presence of a combination of circumstances, where action is necessary, they will know what to do and how to do it. This may look like a very severe dictum to apply to recent graduates, with their limited experience and small accumulation of facts, and yet we cannot help feeling that in some degree this dictum may legitimately be applied even to them, and that if they have been properly trained by the schools they will show in some measure a capacity for meeting unexpected and unforeseen emergencies. But it may be asked, what teaching and what training leads to the development of this capacity? We answer, that while it is undoubtedly true that the mental characteristics of the student himself are a most important factor, and that it is clearly impossible to make thinkers of every student in the class, yet as we understand the matter, that teaching which brings out and keeps prominent before the mind of the student the principles underlying the theme which is under consideration, be the subject of study whatever it may, rather than that teaching which fills the mind of the student with methods, with manipulation, and with accumulated informa-

tion, embracing a taste of many subjects, will have a tendency to develop the kind of mind we are looking for. A somewhat extensive acquaintance with recent graduates from the chemical schools for a number of years past, has led us to fear that methods, manipulation and accumulated information were given undue prominence, and that principles and reasons why were not sufficiently insisted upon. We are clearly of the opinion that the schools truly desire to furnish what is wanted, and that the situation as we seem to find it, is due to the effort on the part of the schools to turn out their graduates, fitted to at once begin to earn a livelihood or perchance to take charge of independent work. We are compelled to say that, while the motive seems praiseworthy, and a legitimate yielding to the demands of the times, we cannot help feeling that many a graduate will, under such tutelage, fail to reach the success which, with a different method, would have been legitimately in his grasp.

Perhaps an illustration will make clear the difference in methods of teaching which we have in mind. Not long ago we separately asked three recent graduates, each one from a different, entirely reputable school, why nitric acid is used to dissolve steel, when one is going to determine the phosphorus. Why not use some other acid just as well? Two of the three replied that they supposed that nitric acid was a good solvent for steel, and they knew of no reason why any other acid that would dissolve the steel would not do as well. The third answered that in order to take the next step in the process, it was essential that the phosphorus should exist as ortho-phosphoric acid, and that nitric acid being an oxidizing agent would bring the phosphorus to that condition. Now each of these three recent graduates knew how to determine phosphorus in steel, and as a matter of fact each of them had done it in an entirely acceptable manner and under check for six months or more in my own laboratory. All three of them were familiar with the method and with the manipulation. But as we look at it only one of them had been properly taught. He not only knew the method and the manipulation, but he also knew the reasons why, and the principles underlying the method. One of my assistants put the matter very forcibly. He said: "The chemist who knows methods and manipulation gets along swimmingly as long as everything goes well, and perhaps turns out more work

in a day than a thinking chemist who understands the reason why for every step in his analysis, but let a difficulty arise, and your method chemist is absolutely lost."

There is another phase of this case which is perhaps worthy of a moment's notice. Given two young men of equal ability, and let both of them go through good technical schools, both graduating say as chemists, or as mining, mechanical, civil or electrical engineers. The one during his course of study has covered much ground, has stored his mind with facts, has learned carefully, and well, the methods and manipulation required in the branch chosen. The other has not covered so much ground, but every bit of information that he has, he thoroughly understands; he has acquired principles rather than a large array of facts, and he knows the reason why. Let now these two begin work after graduation in the same place, and we are ready to confess that the former will make the best showing, and progress the more rapidly for the first year or two, but if our observation is worth anything, the latter will distance his competitor at the end of ten years.

But we are perhaps spending too much time over this point. The mental equipment which the schools furnish is only a fraction of that needed by the Testing Engineer, especially if he happens to have it as his field of work, to defend the interests of a great consumer. It is legitimate and reasonably to be expected that the schools should teach a young man how to learn, and should start him in a number of subjects; but his real education comes later. We often say to our young men that the two things that a recent graduate needs most are experience and acquaintance. Under the head of experience, we comprehend the arranging of the information already acquired, so that each part will have its due, and only its due prominence, the accumulation of additional information, either by reading, by close and continuous study of his main theme or related branches—we fancy it almost goes without saying that the man who expects to reach even moderate success as a Testing Engineer, must study harder the first five or ten years after graduation, than he did at any time while in school—we say a man must accumulate experience by arranging the information already acquired, by reading, by study, and actual contact with industrial processes, and with the world's work, in every possible detail, and above all, a man must acquire experience by

actual wrestling with problems that may be committed to his care. It is apparently not essential, in order to gain experience, that one should successfully solve his problems. Faraday was accustomed to say that he actually learned more by his failures, than from his successes. We cannot, we think, too emphatically insist on the importance to the Testing Engineer, of self education, of the broadening of his field of knowledge and of the acquisition of facts. The Testing Engineer should be an omnivorous student. Nothing too trivial to interest him, nothing too remote from his present line of work to make a legitimate demand on his attention should opportunity offer. The schools, if they have done their duty, have given you a more or less trained mind, and have taught you how to learn. It is your own fault if you do not broaden every day. You can never tell what moment you will need, and badly need, some out of the way fact. Store them up against that time of need.

Perhaps you will forgive me an illustration or two on this point. We recently saw a broken steel car axle. The break occurred ten or twelve inches from the end of the axle. On examining both ends, there was some appearance of seams, not radial, but rather in a sense irregularly parallel to the circumference. These seams suggested that probably the axle was made from a billet coming from somewhere near the top of the ingot, and that the seams were in some way connected with the pipe. It was reasoned that if this were true, an analysis of the metal from the surface and from the center of the cross section of the axle would show segregation, and that if, for example, much higher phosphorus were found in the center than at the circumference, it would almost be a demonstration of the location of the billet. Of course the whole object of the study was to see if any information could be obtained that would prevent the acceptance of such bad axles in the future. It should be mentioned that the broken-off piece was sawed in two lengthwise, and that when this was done, from one of the halves a core amounting to about a third of the cross sectional area actually fell out, showing that the seam indications at the end were genuine, and that the seam did actually exist. The analysis above referred to was made, and to our astonishment showed lower phosphorus in the center than in the circumference. This seemed to settle the question as to the relation between the seam and the pipe and,

indeed, we regarded it as conclusive evidence that the billet from which this axle was made was not taken from too high up in the ingot, but it left unsettled the cause of the seam. Perhaps, however, a few words farther on certain well-known phenomena in steel metallurgy will help us in clearing up the point. It is obvious that if in a big ingot, a portion of it contains more than the normal amount of phosphorus, carbon or sulphur, as is actually the fact in the case of segregation, it must follow that there will be parts of the ingot which will contain less than the normal amounts of these constituents. It is generally assumed that the outside of a forging like an axle gives very close to the normal analysis of the steel, since from the method of manufacture this outer metal was near the surface of the ingot when the metal was cast, and consequently cooled too quickly to permit perceptible segregation. Also if we are right, the analysis of borings taken from different parts of the inner face of an ingot sawed in two lengthwise for the purpose, shows that phosphorus, carbon and sulphur, near the middle of the lower third of the ingot, are usually below the normal. Now since the phosphorus in the center of our axle was lower than in the circumference, it seems evident that the billet from which it was made must have been from somewhere in the lower third of the ingot. Apparently, therefore, we must look here for the cause of the seams. The steel makers present have undoubtedly sometime since foreseen the cause of the difficulty with this axle. For the benefit of the others we may say that seamy bottoms of ingots are now usually explained by wet or insufficiently dried bottoms of ingot moulds. The steam or other volatile material generated by the heat of the molten metal, can apparently only escape up through the molten metal itself, forming a seam, which the subsequent treatment does not weld up.

Another brief illustration will perhaps emphasize the importance to the Testing Engineer of familiarity with the minute details of industrial processes. A couple of years ago, while the finishing cut was being taken on a steel driving axle in a lathe, the operator noticed in the freshly cut surface what appeared to be a small flaw. On testing this with a pin, the pin disappeared, and quite a length of fine wire followed it. On taking out a transverse slice of the axle at this point, a cavity was found in the metal, which would hold half a pint or more. The walls of the cavity were perfectly

clean and bright, and but for the fact that the finishing cut just happened to open up the cavity a trifle, its presence would not have been suspected, and the axle would have gone into service. It is perhaps safe to say that one-quarter or possibly one-third of the cross sectional area of the axle was embraced in the cavity. We have seen a number of such cases, and unfortunately the phenomenon is not too rare. Almost any practical steel maker, when asked for the cause of such a cavity in what is apparently a solid piece of metal, would probably laconically answer, "careless heater." In order to understand this statement, it is necessary to say that many driving axles even when they are finished, are about eleven inches in diameter, and that the bloom from which they are forged is considerably larger. If now such a bloom when cold is put into a hot furnace, the outside layers get hot long before the inside has begun to raise much in temperature. A severe strain, due to the greater expansion of the outside layers, is accordingly set up, which strain is enough occasionally to actually rupture the inside. Subsequent forging opens out this rupture into a cavity. The rupture is usually accompanied by a noise like a pistol shot. The unfortunate part of the business is that there being a number of blooms in the furnace at one time, it is impossible to tell which one has yielded to the strain. As would be expected, the larger the axle the more common this defect, and we know of one large railroad that bores a two-inch hole through every axle over eight inches in diameter that is destined for passenger service. The boring of the hole enables the cavity to be discovered, either by the behavior of the drill, or by sight examinations after the hole is finished. It is interesting to know that something over two per cent. of all axles bored are defective in this way.

One or two points more, and we have finished. It may seem an idle question, but it is certainly an interesting one, as to which of the three kinds of Testing Engineers has the most attractive field of work. The unattached testing engineer certainly has the greatest freedom, but at the same time the least stimulus. The producer's Testing Engineer undoubtedly has the best financial reward, but at the same time the narrower field. He has, however, the advantage of concentration, and as almost every modern industry has scores of unsolved problems connected with it, there is no reason, if he will work, why he should not achieve a great

success. On the other hand, the consumer's Testing Engineer has unquestionably the broader field, the greater chance for initiative, and perhaps more important than all, an opportunity to study the behavior of materials in actual service. This last item gives him a great advantage. The behavior in service is unquestionably the ultimate criterion by which every industrial product must be judged, and by whose decision, sooner or later, it must stand or fall. Undoubtedly, individual characteristics are a legitimate element in the choice, but our counsel would be to every ambitious Testing Engineer, to get as near to the service as possible, and to this end to make some sacrifices if necessary, to secure a position with a consumer.

And this brings us to another point. We have many times heard complaints of the dullness and unsatisfactoriness of spending one's days and weeks in making routine tests. We are compelled to say that we do not understand this. It is one of our sincere regrets that we are no longer able to do routine work. To us there is genuine pleasure in seeing how the test comes out in each individual case, although we may have performed the same operation over and over again. Moreover, there is scarcely a method in use to-day, either in chemical or physical testing that is not capable of improvement, either in accuracy or speed, or both, and what better opportunity for suggestions could be desired than is furnished while the hands are busy doing that which from long practice they do almost automatically, and with the attention necessarily directed to the subject in hand, leaving the mind almost free to dwell on possible changes leading to progress. Some of our very best thoughts have come to us while engaged in routine work. One is very near to Nature's heart when making tests, even routine tests, and if his mind at such times is alert and receptive she will not infrequently give him a hint or disclose a fraction of some of her secrets to his view.

There is one more phase of the work of the Testing Engineer which will perhaps bear a few words, and that is the relation between the Testing Engineer and those whose material he is testing. This is unquestionably a delicate subject, one that we would all gladly feel did not need discussion or comment, and yet one that is constantly thrusting itself into prominence, in some form. For the honor of human nature, it is gratifying to be able to put

on record that during nearly thirty years of almost constant testing, only once have direct financial considerations been urged upon us to influence our verdict in regard to material. On the other hand, we have heard representatives of entirely reputable business organizations say openly, "It costs us something to sell our goods, and it is entirely immaterial to us whether this money goes to our selling agents, or to the representatives of the consumers." And this is not the worst phase of the matter. It is well known that the representatives of consumers who act in some sense in the capacity of Testing Engineers, in that their opinion or decision determines the placing of orders, not only accept substantial considerations, from producers, but even demand them, if not openly, at least indirectly. The subject is one on which much might be said. An hour could readily be filled in narrating incidents and portraying the forms in which the hydra-headed monster, graft, manifests itself. We are confident that neither side is free from blame: we are equally confident that strict, open honesty is the only safe course. It may not be amiss to add that so insidious are the forms in which this evil manifests itself, that, in the words of the Scripture, they would at times deceive the very elect, and while it is not possible to discuss these matters, without raising interminable questions of casuistry and metaphysics, it is possible to so act as to have the continuous approval of a good, clean conscience. No universal rule can be given. Each one in a sense must be a law unto himself. Perhaps the best every-day working rule for young Testing Engineers is, do nothing you would not be willing to talk over with your employer, even in the presence of the other party. It is sometimes a bit hard to resist and say "no," but of one thing be sure—every departure from strict integrity will, sooner or later, return to plague you, and should your actions ultimately result in your downfall, from none will you get less sympathy than from those who may have contributed to your disaster.

REPORT OF COMMITTEE A ON STANDARD SPECIFICATIONS FOR IRON AND STEEL.

At the last annual meeting of the Society it was resolved, "That Committee A be instructed to consider the revision of the Standard Specifications for Iron and Steel with a view of bringing them into harmony, if possible, with those proposed or adopted by other societies or committees; that the report of Committee A on this subject, embodying its reasons for such recommendations as it may offer, shall be printed a sufficient length of time in advance of the next annual meeting to give ample opportunity for written discussion."

In pursuance of this action a meeting of Committee A was held in Philadelphia on December 9–10, 1904. This meeting was attended by nineteen members of Committee A and by numerous representatives of committees of other societies engaged on similar work. Four sessions were held presided over by President Charles B. Dudley and Mr. C. C. Schneider, at which the following specifications were considered:

I. Standard Specifications for Structural Steel for Bridges and Ships.
II. Standard Specifications for Open-hearth Boiler Plate and Rivet Steel.
III. Standard Specifications for Steel Rails.
IV. Standard Specifications for Steel Castings.
V. Standard Specifications for Steel Axles.
VI. Standard Specifications for Steel Forgings.

The criticisms advanced against these specifications by the committees of other societies were fully discussed and the following action was taken:

I. *Standard Specifications for Structural Steel for Bridges and Ships.*

It was decided (1) to strike out the words "*Bridges and*" from the title of these specifications with a view of making them applica-

ble hereafter to ship material only; and (2) to recommend the adoption under the title, "Standard Specifications for Structural Steel for Bridges," the "Specifications for Material for Steel Structures," adopted by the American Railway Engineering and Maintenance of Way Association with amendments approved in March, 1904.* It will be remembered that the specifications adopted by the American Society for Testing Materials, then known as the American Section of the International Association for Testing Materials, served as the basis for these specifications. The only changes recommended by Committee A and embodied in the proposed standard specifications appended to this report are as follows:

Clause 3. Change "a retest *shall* be made" to "a retest *may* be made."

Clause 11, (*a*), (*b*) and (*c*). Strike out the words "*per cent.*" after 2½, 1 and 5 in (a), (b) and (c) respectively, and substitute "*percentage of elongation*" for "*elongation*" in each of these paragraphs.

It should be stated that at the meeting of the American Railway Engineering and Maintenance of Way Association, held in Chicago, in March of this year, the above proposed change in Clause 3 was not approved.

The proposed modification of Clause 11 is merely in the interest of definiteness, the original form being somewhat ambiguous.

II. *Standard Specifications for Open-hearth Boiler Plate and Rivet Steel.*

A Committee of the American Society of Mechanical Engineers recommended in 1903 the following changes in these specifications:†

1. That the maximum sulphur in flange or boiler steel be reduced from 0.05 to 0.04.
2. That fire-box steel be specified at 55,000 pounds per square inch with an allowable variation of 5,000 pounds above or below, instead of 57,000 pounds per square inch with a like variation. That the determination of the yield point for ordinary grades be omitted.

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* Proceedings, Vol. III, pp. 59–68, and Vol. IV, 199–200.

† *Ibid*, Vol. III, pp 82–88.

It was decided not to accept these changes since no specific reason for the same had been advanced and since the specifications in their present form are in harmony with those of the American Master Mechanics' Association. It should be added that invitations to attend the meeting were extended to the members of the Committee of the American Society of Mechanical Engineers, but that no member of that committee was present.

III. *Standard Specifications for Steel Rails.*

It was decided to recommend the adoption under the title, "Standard Specifications for Steel Rails," the specifications adopted by the American Railway Engineering and Maintenance of Way Association,* based originally on our own specifications and appended to this report, subject to the following changes:

Clause 3. Change "from *each* blow" to "from *every fifth* blow." Strike out the word "*preferably.*" Change heights of drop for 65–75, 75–85 and 85–100-pound rails from "18, 20 *and* 22 *feet*," to "17, 18 *and* 19 *feet*," respectively, as in the present standard specifications.

It was thought that since it is proposed to specify hereafter that "the test shall be taken from the top of the ingot," the number of tests should not be increased nor the heights of drop.

At the recent meeting of the American Railway Engineering and Maintenance of Way Association it was decided to strike out the word "*preferably*" but to make no other changes in this clause.

Clause 4. That action on this clause be deferred pending the report of a sub-committee on the conditions at the various rail-mills affecting the amount of shrinkage. The following members have been appointed on this sub-committee: J. T. Richards, chairman, W. A. Bostwick, P. E. Carhart, R. W. Hunt, E. F. Kenney and S. S. Martin. It is expected that the report of this sub-committee will be available for consideration at the regular fall meeting of Committee A to which the committees of other societies will be invited.

Clauses 7 *and* 8. To be recommended for adoption after they have been harmonized by the American Railway Engineering and Maintenance of Way Association.

* Proceedings, Vol. IV, pp. 195–198

Clause 9. Change "33 *feet*" to "30 *feet*," and "27 *feet*" to "24 *feet*."

It was considered inadvisable to adopt 33 feet as the standard length owing to the lack of suitable transportation equipment on the part of the railroads, especially in the East, for handling rails 33 feet long. Moreover, the 30 foot length is better adapted to the usual size of ingot for 100-pound rails, and, at some mills, to the position of the cambering machine relative to the finishing rolls.

Clause 14. Change "*five* per cent." to "*ten* per cent." Strike out "*rails rejected under the drop test will not be accepted as No. 2 rails.*"

It was thought that limiting No. 2 rails to five (5) per cent. of the whole order would impose an unwarranted hardship on the manufacturers, especially in the case of heavy rails, for which the percentage of No. 2 rails is usually in excess of five (5).

IV. *Standard Specifications for Steel Castings.*

The changes in these specifications recommended by the Committee of the American Society of Mechanical Engineers* are:

1. That the tensile strength of soft, medium and hard castings be changed from specified minimum values of 60,000, 70,000 and 85,000 pounds per square inch to 60,000, 70,000 and 80,000 pounds respectively, with allowable variations of 5,000 pounds above and below these values.

This recommendation was not accepted because there is apparently no good reason for prescribing an upper limit, and it was thought better not to set such a limit.

2. That the 8-inch specimen be made the standard specimen, and that the 2-inch specimen be used only when it is inconvenient to use the 8-inch one; and that an increase in elongation of 25 per cent. be required for the former.

* Proceedings, Vol. III, pp. 82–88.

For comparison the values are here tabulated:

Grade	A. S. T. M. 2-in. spec.	Comm. A. S. M. E. 2-in. spec.	Comm. A. S. M. E. 8-in. spec.
Soft	22%	20 %	16%
Medium	18%	17.5%	14%
Hard	15%	15 %	12%

In the judgment of the Committee the additional cost of preparing 8-inch specimens is unwarranted and accordingly no change is recommended. Apparently no good reason exists for reducing the percentages of elongation.

The only change recommended in these specifications is that in Clause 1 the words, "Castings to be annealed or unannealed as specified," be changed to "Castings to be annealed unless otherwise specified."

V. *Standard Specifications for Steel Axles.*

VI. *Standard Specifications for Steel Forgings.*

The changes in these specifications recommended by the Committee of the American Society of Mechanical Engineers * are:

1. That nickel-steel forgings and oil-tempered forgings be not included in this specification, because the present state of the art does not warrant general specifications being drawn for these materials.

This recommendation was not accepted because of the large use of such forgings.

2. That for soft or low-carbon steel forgings the chemical requirements be not over 0.06 phosphorus, and 0.05 sulphur, instead of 0.10 phosphorus and 0.10 carbon.

This suggested change was not approved because of the large use of that grade of forgings.

* Proceedings, Vol. III, pp. 82–88.

3. That for "carbon steel not annealed" the term "medium steel" be used, and that the sulphur be reduced from 0.06 to 0.05 per cent.

It was thought inadvisable to make this change.

4. That, wherever it is desirable that the elastic limit be determined, an extensometer be used, and that the elastic limit be taken as "that point at which the elongation in 8 inches per 1,000 pounds of added stress per square inch first exceeds four ten-thousandths of an inch."

This suggestion was not accepted because it was considered commercially impracticable.

It was decided to recommend the adoption of specifications for locomotive axles and forgings, compromising the differences between the above specifications and those of the American Railway Master Mechanics' Association, in accordance with the plan proposed by Mr. H. V. Wille.*

The proposed requirements are as follows:

(*a*) Phosphorus, 0.05; sulphur, 0.05; manganese, 0.60; tensile strength, 80,000; elongation, 20 per cent.; reduction of area, 25 per cent.; bending, 1 x ½-inch test-piece, 180° over 1 inch diameter.

It is proposed to modify the present standard specifications for steel axles and forgings by embodying the above requirements specifically for locomotive forgings.

The above results of the action taken at the meeting of the Committee were submitted to letter-ballot of the Committee and approved, and they are now submitted to the Society for such action as it may see fit to take.

As illustrative of the increasing tendency to cooperation on the part of committees representing different societies but engaged on similar work, and of their desire to proceed in harmony with this Committee, the report of the Committee on Rail Sections of the American Society of Civil Engineers, presented last January is here quoted:

* Proceedings, Vol. IV, pp. 201–203.

"Your Committee respectfully report that during the year they have given consideration to the work of committees on rail specifications which have been appointed by the American Railway and Maintenance of Way Association, the American Society for Testing Materials, and the Engineering Standards Committee (Great Britain), and with which committees yours is working in harmony.

"Your Committee has also obtained and discussed data pertaining to the service of rails made by different metallurgical processes, and under various specifications. In addition to this, they are keeping record of the use by American and other railways of rails of the American Society's sections.

"In the judgment of your Committee all of this will enable them to make later a more definite report to the Society. However, in the meantime, they would report that correspondence with the Engineers of the Railways of the United States and Canada, evidences that while the wear of the heavier sectioned rails is not so satisfactory as that of the lighter ones, at the same time there is not a demand on the part of said railways for a change in any of the American Society's sections. In addition to this, a conference with a committee representing American Steel Rail Manufacturers elicited from said committee the statement that the manufacturers were entirely satisfied with the American Society's sections.

"In view of the above, your Committee does not now recommend any change in the American Society's sections.

"Inasmuch as the committees of the several societies above named hope soon to reach definite conclusions, and in view of the International Railway Congress to be held in Washington, D. C., in May next, your Committee think it well that their labors be continued, and therefore respectfully ask for such authority."

It is proposed to hold a meeting of this Committee in the fall, to which the members of the committees of other societies interested in the subjects to be discussed will be again invited with a view of harmonizing any remaining differences. It is intended also to consider at that meeting the revision of the Standard Specifications for Structural Steel for Ships in the light of other current American specifications, and the specifications for hull material recently prepared by the British Engineering Standards Committee.

As a matter of general interest and one bearing directly on the question of specifications for steel rails, the following official instructions for 1905–06 to the Committee on Rail, of the American Railway Engineering and Maintenance of Way Association are here quoted:

Frequency of occurrence, cause and recommended remedy for piped rails. Recommendation as to limiting the number of standard rail sections. Recommendation as to changing standard rail sections of American Society of Civil Engineers, conferring with Track Committee. Statistics as to life of rails. Statistics as to breakage of rails and causes. Statistics as to the rail industry, annual consumption (American manufacture and imported), cost of rail, probable life of rail, track mileage, etc., for various periods, preferably from year to year, with a view to showing by comparative statistics the difference as to average life and annual cost per mile of rails manufactured in recent years, as compared with the results obtained in earlier periods. Prepare list of definitions.

As is well known, the Engineering Standards Committee of Great Britain is operating on lines very similar to those pursued by many of our own Committees. A special meeting of Committee A was held in New York last fall in order to meet the Secretary of the English committee who had come to this country on an official visit "to study the question of standardization in the United States and Canada." This meeting was well attended and gave our members a favorable opportunity to receive first-hand information concerning the present very active movement in England looking to the standardization of engineering products and specifications. Since this movement touches many of the interests represented by our various standing committees, and since it is understood that it will receive due attention in the annual report of the Executive Committee further reference to the subject is omitted here.

Appended to this report are (1) Proposed Standard Specifications for Structural Steel for Bridges, and (2) Specifications for Steel Rails, American Railway Engineering and Maintenance of Way Association.

Respectfully submitted,

WILLIAM R. WEBSTER,
Chairman.

EDGAR MARBURG,
Secretary.

APPENDIX I.

PROPOSED STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BRIDGES.

Manufacture. 1. Steel shall be made by the open-hearth process.

Chemical Composition. 2. The chemical and physical properties shall conform to the following limits:

Elements Considered.	Structural Steel.	Rivet Steel.	Steel Castings.
Phosphorus Max. Basic	0.04 per cent.	0.04 per cent.	0.05 per cent.
Phosphorus Max. Acid	0.08 "	0.04 "	0.08 "
Sulphur Max.	0.05 "	0.04 "	0.05 "
Ult. tensile strength .. Pounds per sq. in. .	Desired 60,000	Desired 50,000	Not less than 65,000
Elong.: Min. per cent. in 8 in. (Fig. 1) ...	$\frac{1{,}500{,}000^{*}}{\text{Ult. tens. str.}}$	$\frac{1{,}500{,}000}{\text{Ult. tens. str.}}$	
Elong.: Min. per cent. in 2 in. (Fig. 2)	22	....	18
Character of fracture	Silky	Silky	Silky or fine granular.
Cold bend without fracture	180 degrees flat†	180 degrees flat‡	90 degrees.

* See par. 11. † See par. 12, 13 and 14. ‡ See par. 15.

The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

Retests. 3. Tensile tests of steel showing an ultimate strength within 5,000 lbs. of that desired will be considered satisfactory, except that if the ultimate strength varies more than 4,000 lbs. from that desired, a retest may be made on the same gauge, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate.

Chemical Determination. 4. Chemical determinations of the percentages of carbon, phosphorus, sulphur and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel and a correct copy of such analysis shall be furnished to the engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent. above the required limits will be allowed.

Plates, Shapes and Bars. 5. Specimens for tensile and bending tests for plates, shapes

and bars shall be made by cutting coupons from the finished product, which shall have both faces rolled and both edges milled to the form shown by Fig. 1; or with both edges parallel; or they may be turned to a diameter of ¾ inch for a length of at least 9 inches, with enlarged ends.

Rivets.

6. Rivet rods shall be tested as rolled.

Pins and Rollers.

7. Specimens shall be cut from the finished rolled or forged bar in such manner that the center of the specimen shall be 1 inch from the surface of the bar. The specimen for tensile test shall be turned to the form shown by Fig. 2. The specimen for bending test shall be 1 inch by ½ inch in section.

Steel Castings.

8. The number of tests will depend on the character and importance of the castings. Specimens shall be cut cold from coupons molded and cast on some portion of one or more castings from each melt or from the sink-heads, if the heads are of sufficient

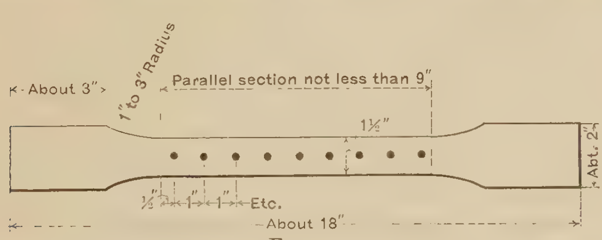


FIG. 1.

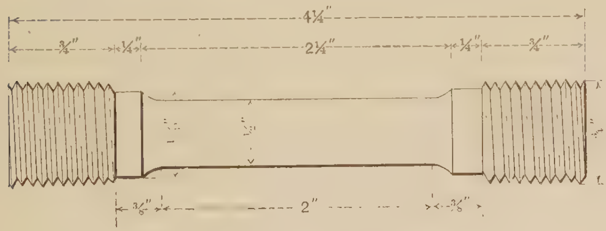


FIG. 2.

size. The coupon or sink-head, so used, shall be annealed with the casting before it is cut off. Test specimens to be of the form prescribed for pins and rollers.

Conditions for Tests.

9. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimens for tensile tests, representing such

material, shall be cut from properly annealed or similarly treated short lengths of the full section of the bar.

Number of Tests. 10. At least one tensile and one bending test shall be made from each melt of steel as rolled. In case steel differing $\frac{3}{8}$ inch and more in thickness is rolled from one melt, a test shall be made from the thickest and thinnest material rolled.

Elongation. 11. For material less than 5-16 inch and more than $\frac{3}{4}$ inch in thickness the following modifications will be allowed in the requirements for elongation:

(*a*) For each 1-16 inch in thickness below 5-16 inch, a deduction of $2\frac{1}{2}$ will be allowed from the specified percentage of elongation.

(*b*) For each $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch, a deduction of 1 will be allowed from the specified percentage of elongation.

(*c*) For pins and rollers over 3 inches in diameter the percentage of elongation in eight inches may be 5 less than that specified in paragraph 2.

Bending Tests. 12. Bending tests may be made by pressure or by blows. Plates, shapes and bars less than 1 inch thick shall bend as called for in paragraph 2.

Full sized Bends. 13. Full-sized material for eye-bars and other steel 1 inch thick and over, tested as rolled, shall bend cold 180° around a pin the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of bend.

Tests for Angles. 14. Angles $\frac{3}{4}$ inch and less in thickness shall open flat, and angles $\frac{1}{2}$ inch and less in thickness shall bend shut, cold, under blows of a hammer, without sign of fracture. This test will be made only when required by the inspector.

Tests on Rivet Steel. 15. Rivet steel, when nicked and bent around a bar of the same diameter as the rivet rod, shall give a gradual break and a fine, silky, uniform fracture.

Finish. 16. Finished material shall be free from injurious seams, flaws, cracks, defective edges, or other defects, and have a smooth uniform, workmanlike finish. Plates 36 inches in width and under shall have rolled edges.

Marking. 17. Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it.

Steel for pins and rollers shall be stamped on the end. Rivet and lattice steel and other small parts may be bundled with the above marks on an attached metal tag.

18. Material which, subsequent to the above tests at the mills and its acceptance there, develops weak spots, brittleness, cracks or other imperfections, or is found to have injurious defects, will be rejected at the shop and shall be replaced by the manufacturer at his own cost. **Rejections.**

19. A variation in cross-section or weight of each piece of steel of more than 2½ per cent. from that specified will be sufficient cause for rejection, except in case of sheared plates, which will be covered by the following permissible variations, which are to apply to single plates. **Permissible Variations.**

WHEN ORDERED TO WEIGHT.

20. Plates 12½ pounds per square foot or heavier: **Permissible Variations.**

(*a*) Up to 100 inches wide, 2½ per cent. above or below the prescribed weight.

(*b*) One hundred inches wide and over, 5 per cent. above or below.

21. Plates under 12½ pounds per square foot:

(*a*) Up to 75 inches wide, 2½ per cent. above or below.

(*b*) Seventy-five inches and up to 100 inches wide, 5 per cent. above or 3 per cent. below.

(*c*) One hundred inches wide and over, 10 per cent. above or 3 per cent. below.

WHEN ORDERED TO GAUGE.

22. Plates will be accepted if they measure not more than 0.01 inch below the ordered thickness. **Permissible Variations.**

23. An excess over the nominal weight corresponding to the dimensions on the order, will be allowed for each plate, if not more than that shown in the following tables, one cubic inch of rolled steel being assumed to weigh 0.2833 pound.

24. Plates ¼ inch and over in thickness.

Thickness Ordered.	Nominal Weights.	Width of Plate.			
		Up to 75 inch.	75″ and up to 100.″	100″ and up to 115.″	Over 115.″
1-4 inch.	10.20 lbs.	10 per cent.	14 per cent.	18 per cent.	
5-16 "	12.75 "	8 " "	12 " "	16 " "	
3-8 "	15.30 "	7 " "	10 " "	13 " "	17 per cent
7-16 "	17.85 "	6 " "	8 " "	10 " "	13 " "
1-2 "	20.40 "	5 " "	7 " "	9 " "	12 " "
9-16 "	22.95 "	4½ " "	6½ " "	8½ " "	11 " "
5-8 "	25.50 "	4 " "	6 " "	8 " "	10 " "
Over 5-8 "	....	3½ " "	5 " "	6½ " "	9 " "

Inspection and Testing.

25. Plates under ¼ inch in thickness.

Thickness Ordered.	Nominal Weights. Lbs. per square ft.	Width of Plate.		
		Up to 50.″	50″ and up to 70.″	Over 70.″
1-8″ up to 5-32″	5.10 to 6.37	10 per cent.	15 per cent.	20 per cent.
5-32″ " 3-16″	6.37 " 7.65	8½ " "	12½ " "	17 " "
3-16″ " 1-4″	7.65 " 10.20	7 " "	10 " "	15 " "

26. The purchaser shall be furnished complete copies of mill orders, and no material shall be rolled, nor work done, before the purchaser has been notified where the orders have been placed, so that he may arrange for the inspection.

27. The manufacturer shall furnish all facilities for inspecting and testing the weight and quality of all material at the mill where it is manufactured. He shall furnish a suitable testing machine for testing the specimens, as well as prepare the pieces for the machine, free of cost.

28. When an inspector is furnished by the purchaser to inspect material at the mills, he shall have full access, at all times, to all parts of mills where material to be inspected by him is being manufactured.

APPENDIX II.

SPECIFICATIONS FOR STEEL RAILS.

ADOPTED BY THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION.

Process of Manufacture.

(1) (a) The entire process of manufacture and testing shall be in accordance with the best current practice, and special care thall be taken to conform to the following instructions:

(b) Ingots shall be kept in a vertical position in the pit heating furnaces until ready to be rolled, or until the metal in the interior has time to solidify.

(c) No bled ingots shall be used.

(d) Sufficient material shall be discarded from the top of ingot to insure sound rails.

Chemical Composition.

(2) Rails of the various weights per yard specified below shall conform to the following limits in chemical composition:

	50 to 59 Pounds. Per cent.	60 to 69 Pounds. Per cent.	70 to 79 Pounds. Per cent.	80 to 89 Pounds. Per cent.	90 to 100 Pounds. Per cent.
Carbon	0.35-0.45	0.38-0.48	0.40-0.50	0.43-0.53	0.45-0.55
Phosphorus, shall not exceed	0.10	0.10	0.10	0.10	0.10
Silicon, shall not exceed	0.20	0.20	0.20	0.20	0.20
Manganese	0.70-1.00	0.70-1.00	0.75-1.05	0.80-1.10	0.80-1.10

Drop Test (one from each heat).

(3) One drop test shall be made on a piece of rail not less than four feet and not more than six feet long, selected from each blow of steel. The test shall, preferably, be taken from the top of the ingot. The rail shall be placed head upwards on the supports, and the various sections shall be subjected to the following impact tests under a free falling weight:

	Weight of Rail. Pounds Per Yard.	Height of Drop. Feet.
	45 to and including 55	15
More than	55 " 65	16
More than	65 " 75	18
More than	75 " 85	20
More than	85 " 100	22

If any rail break when subject to the drop test, two additional tests will be made of other rails from the same blow of steel, and

if either of these latter tests fail, all the rails of the blow which they represent will be rejected, but if both of these additional test pieces meet the requirements, all the rails of the blow which they represent will be accepted.

(4) The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws of 6 in. for 85-pound and $6\frac{1}{8}$ in. for 100-pound rails, and no artificial means of cooling the rails shall be used between the finishing pass and the hot saws. The above shrinkage allowance may be varied, if necessary, so as to give a finishing temperature of not exceeding 1,600 degrees Fahrenheit at finishing rolls for mills rolling from reheated blooms, and not exceeding 1,750 degrees Fahrenheit at finishing rolls for mills rolling direct from the bloom to finish rail.

Drop Testing Machine. (5) The drop testing machine shall have a tup of two thousand (2,000) pounds weight, the striking face of which shall have a radius of not more than five (5) inches, and the test rail shall be placed head upwards on solid supports three (3) feet apart. The anvil block shall weigh at least twenty thousand (20,000) pounds, and the supports shall be part of, or firmly secured to, the anvil. The report of the drop test shall state the atmospheric temperature at the time the test was made.

Chemical Analyses. (6) The manufacturer shall furnish the inspector, daily, with carbon determinations for each blow, and a complete chemical analysis every twenty-four hours, representing the average of the other elements contained in the steel, for each day and night turn. These analyses shall be made on drillings taken from small test ingot.

Section. (7) Unless otherwise specified, the section of rail shall be the American Standard, recommended by the American Society of Civil Engineers, and shall conform, as accurately as possible, to the templet furnished by the railroad company, consistent with paragraph No. 8, relative to specified weight. A variation in height of one-sixty-fourth (1-64) of an inch less, or one thirty-second (1-32) of an inch greater than the specified height, and one-sixteenth (1-16) inch in width will be permitted. The section of rail shall conform perfectly to the finishing dimension.

Weight. (8) The weight of the rails will be maintained as nearly as possible, after complying with paragraph No. 7, to that specified

in contract. A variation of one-half ($\frac{1}{2}$) of one per cent. for an entire order will be allowed. Rails shall be accepted and paid for according to actual weights.

(9) The standard length of rails shall be thirty-three (33) feet. Ten per cent. of the entire order will be accepted in shorter lengths, varying by even feet to twenty-seven (27) feet, and all No. 1 rails less than 33 feet shall be painted green on the end. A variation of one-fourth of an inch in length from that specified will be allowed. **Length.**

(10) Circular holes for splice bars shall be drilled in accordance with the specifications of the purchaser. The holes shall accurately conform to the drawing and dimensions furnished in every respect, and must be free from burrs. **Drilling.**

(11) Rails shall be straight when finished, the straightening being done while cold, smooth on head, sawed square at ends, variation to be not over one-thirty-second (1-32) of an inch, and prior to shipment shall have the burr occasioned by the saw cutting removed and the ends made clean. No. 1 rails shall be free from injurious defects and flaws of all kinds. **Finish.**

(12) The name of the maker, the weight of rail and the month and year of manufacture shall be rolled in raised letters on the side of the web, and the number of blow shall be plainly stamped on each rail where it will not subsequently be covered by the splice bars. **Branding.**

(13) The inspector representing the purchaser shall have free entry to the works of the manufacturer at all times when the contract is being filled, and shall have all reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with the terms of these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment. **Inspection.**

(14) No. 2 rails will be accepted up to five (5) per cent. of the whole order. Rails that possess any injurious defects, or which for any other cause are not suitable for first quality, or No. 1 rails, shall be considered as No. 2 rails; provided, however, that rails which contain any physical defects which impair their strength shall be rejected. The ends of all No. 2 rails shall be painted white in order to distinguish them. Rails rejected under the drop test will not be accepted as No. 2 rails. **No. 2 Rails.**

SUMMARY OF ACTION ON REPORT OF COMMITTEE A, ON STANDARD SPECIFICATIONS FOR IRON AND STEEL.

COMPILED BY THE SECRETARY.

The recommendations embodied in the report of Committee A, on Standard Specifications for Iron and Steel, were formally adopted with the following modifications and amendments:

I. *Standard Specifications for Structural Steel for Bridges.*

Par. 2. In last column of table, after 90 degrees, insert "on diameter equal to three times the thickness (d=3t)".

Par. 3. Strike out the words, "Tensile tests of steel showing an ultimate strength within 5,000 lbs. of that desired will be considered satisfactory except that." Insert the words "at the discretion of the inspector."

The paragraph, as amended, reads as follows:

"If the ultimate strength varies more than 4,000 lbs. from that desired, a retest may be made, at the discretion of the inspector, on the same gage, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate."

Par. 11. In clauses (*a*) and (*b*) strike out the words "of elongation."

Strike out clause (*c*) on account of its inconsistency with Par. 7, defining the size of specimen for tensile tests on pins and rollers.

II. *Standard Specifications for Open-hearth Boiler Plate and Rivet Steel.*

The modifications recommended by the Committee of the American Society of Mechanical Engineers were not accepted, and the present standard specifications were reaffirmed without change.

III. *Standard Specifications for Steel Rails.*

Par. 3. The proposed change of "from *each* blow" to "from *every fifth* blow" was referred back to Committee A for further information.

Insert the words "taken from the top of the ingot," after the words "If any rail break when subject to the drop test, two additional tests."

Par. 4, 7, and 8. Referred to Committee A with power to act.

IV. *Standard Specifications for Steel Castings.*

The changes proposed by the Committee of the American Society of Mechanical Engineers were not accepted. The present standard specifications were reaffirmed, except that Par. 1 be modified as recommended by Committee A.

V. *Standard Specifications for Steel Axles.*

VI. *Standard Specifications for Steel Forgings.*

The changes proposed by the Committee of the American Society of Mechanical Engineers were not accepted.

The modifications for locomotive axles and forgings, recommended by Committee A, were adopted except that the proposed bending test was stricken out.

The proposed revised Standard Specifications for (1) Structural Steel for Bridges, (2) Steel Castings, (3) Steel Axles, and (4) Steel Forgings, recommended by Committee A, and modified as above, were referred to letter ballot of the Society. The returns from this ballot, canvassed on September 1, 1905, resulted affirmatively, as announced in detail in *Circular No.* 23. The revised standard specifications are reprinted in the following pages.

STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BRIDGES.*

Manufacture. 1. Steel shall be made by the open-hearth process.

Chemical Composition. 2. The chemical and physical properties shall conform to the following limits:

Elements Considered.	Structural Steel.	Rivet Steel.	Steel Castings.
Phosphorus Max. Basic	0.04 per cent.	0.04 per cent.	0.05 per cent.
Phosphorus Max. Acid	0.08 "	0.04 "	0.08 "
Sulphur Max.	0.05 "	0.04 "	0.05 "
Ult. tensile strength Pounds per sq. in.	Desired. 60.000	Desired 50,000	Not less than 65,000
Elong.: Min. per cent. in 8 in. (Fig. 1)	1,500,000* / Ult, tens. str.	1,500,000 / Ult. tens. str.	
Elong.: Min. per cent. in 2 in (Fig. 2)	22	....	18
Character of fracture	Silky	Silky	Silky or fine granular.
Cold bend without fracture	180 degrees flat†	180 degrees flat‡	90 degrees. d = 3t

* See par. 11. † See par. 12, 13 and 14. ‡ See par. 15.

The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

Retests. 3. If the ultimate strength varies more than 4,000 lbs. from that desired, a retest may be made, at the discretion of the inspector, on the same gauge, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate.

Chemical Determination. 4. Chemical determinations of the percentages of carbon, phosphorus, sulphur and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel and a correct copy of such analysis shall be furnished to the engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent. above the required limits will be allowed.

Plates, Shapes and Bars. 5. Specimens for tensile and bending tests for plates, shapes

*Adopted by letter-ballot of the Society on September 1, 1905.

and bars shall be made by cutting coupons from the finished product, which shall have both faces rolled and both edges milled to the form shown by Fig. 1; or with both edges parallel; or they may be turned to a diameter of $\frac{3}{4}$ inch for a length of at least 9 inches, with enlarged ends.

Rivets.

6. Rivet rods shall be tested as rolled.

Pins and Rollers

7. Specimens shall be cut from the finished rolled or forged bar in such manner that the center of the specimen shall be 1 inch from the surface of the bar. The specimen for tensile test shall be turned to the form shown by Fig. 2. The specimen for bending test shall be 1 inch by $\frac{1}{2}$ inch in section.

Steel Castings.

8. The number of tests will depend on the character and importance of the castings. Specimens shall be cut cold from coupons molded and cast on some portion of one or more castings from each melt or from the sink-heads, if the heads are of sufficient

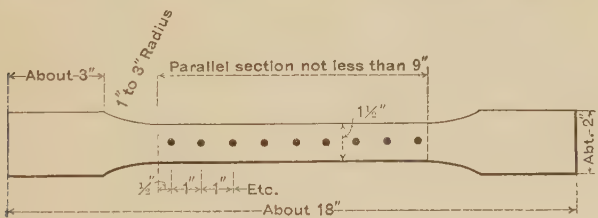


FIG. 1.

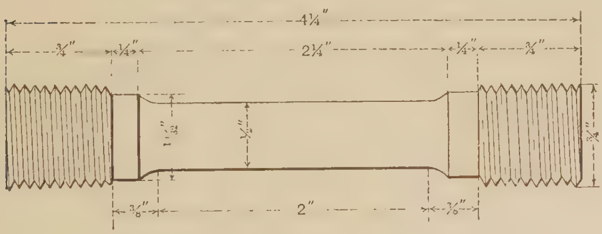


FIG. 2.

size. The coupon or sink-head, so used, shall be annealed with the casting before it is cut off. Test specimens to be of the form prescribed for pins and rollers.

Conditions for Tests.

9. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimens for tensile tests, representing such

material, shall be cut from properly annealed or similarly treated short lengths of the full section of the bar.

Number of Tests.

10. At least one tensile and one bending test shall be made from each melt of steel as rolled. In case steel differing $\frac{3}{8}$ inch and more in thickness is rolled from one melt, a test shall be made from the thickest and thinnest material rolled.

Elongation.

11. For material less than 5-16 inch and more than $\frac{3}{4}$ inch in thickness the following modifications will be allowed in the requirements for elongation:

(*a*) For each 1-16 inch in thickness below 5-16 inch, a deduction of $2\frac{1}{2}$ will be allowed from the specified percentage.
(*b*) For each $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch, a deduction of 1 will be allowed from the specified percentage.

Bending Tests.

12. Bending tests may be made by pressure or by blows. Plates, shapes and bars less than 1 inch thick shall bend as called for in paragraph 2.

Full-sized Bends.

13. Full-sized material for eye-bars and other steel 1 inch thick and over, tested as rolled, shall bend cold 180° around a pin the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of bend.

Tests for Angles.

14. Angles $\frac{3}{4}$ inch and less in thickness shall open flat, and angles $\frac{1}{2}$ inch and less in thickness shall bend shut, cold, under blows of a hammer, without sign of fracture. This test will be made only when required by the inspector.

Tests on Rivet Steel.

15. Rivet steel, when nicked and bent around a bar of the same diameter as the rivet rod, shall give a gradual break and a fine, silky, uniform fracture.

Finish.

16. Finished material shall be free from injurious seams, flaws, cracks, defective edges, or other defects, and have a smooth uniform, workmanlike finish. Plates 36 inches in width and under shall have rolled edges.

Marking

17. Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it. Steel for pins and rollers shall be stamped on the end. Rivet and lattice steel and other small parts may be bundled with the above marks on an attached metal tag.

Rejections.

18. Material which, subsequent to the above tests at the mills and its acceptance there, develops weak spots, brittleness, cracks

or other imperfections, or is found to have injurious defects, will be rejected at the shop and shall be replaced by the manufacturer at his own cost.

Permissible Variations.

19. A variation in cross-section or weight of each piece of steel of more than $2\frac{1}{2}$ per cent. from that specified will be sufficient cause for rejection, except in case of sheared plates, which will be covered by the following permissible variations, which are to apply to single plates.

WHEN ORDERED TO WEIGHT.

Permissible Variations.

20. Plates $12\frac{1}{2}$ pounds per square foot or heavier:
   (*a*) Up to 100 inches wide, $2\frac{1}{2}$ per cent. above or below the prescribed weight.
   (*b*) One hundred inches wide and over, 5 per cent. above or below.

21. Plates under $12\frac{1}{2}$ pounds per square foot:
   (*a*) Up to 75 inches wide, $2\frac{1}{2}$ per cent. above or below.
   (*b*) Seventy-five inches and up to 100 inches wide, 5 per cent. above or 3 per cent. below.
   (*c*) One hundred inches wide and over, 10 per cent. above or 3 per cent. below.

WHEN ORDERED TO GAUGE.

Permissible Variations.

22. Plates will be accepted if they measure not more than 0.01 inch below the ordered thickness.

23. An excess over the nominal weight corresponding to the dimensions on the order, will be allowed for each plate, if not more than that shown in the following tables, one cubic inch of rolled steel being assumed to weigh 0.2833 pound.

24. Plates $\frac{1}{4}$ inch and over in thickness.

Thickness Ordered.	Nominal Weights.	Width of Plate.			
		Up to 75 inch.	75″ and up to 100.″	100″ and up to 115.″	Over 115.″
1-4 inch.	10.20 lbs.	10 per cent.	14 per cent.	18 per cent.	
5-16 "	12.75 "	8 " "	12 " "	16 " "	
5-8 "	15.30 "	7 " "	10 " "	13 " "	17 per cent.
7-16 "	17.85 "	6 " "	8 " "	10 " "	13 " "
1-2 "	20.40 "	5 " "	7 " "	9 " "	12 " "
9-16 "	22.95 "	$4\frac{1}{2}$ " "	$6\frac{1}{2}$ " "	$8\frac{1}{2}$ " "	11 " "
5-8 "	25.50 "	4 " "	6 " "	8 " "	10 " "
Over 5-8 "	....	$3\frac{1}{2}$ " "	5 " "	$6\frac{1}{2}$ " "	9 " "

Inspection and Testing.

25. Plates under ¼ inch in thickness.

Thickness Ordered.	Nominal Weights. Lbs. per square ft.	Width of Plate. Up to 50."	50" and up to 70."	Over 70."
1-8" up to 5-32"	5.10 to 6.37	10 per cent.	15 per cent.	20 per cent.
5-32" " 3-16"	6.37 " 7.65	8½ " "	12½ " "	17 " "
3-16" " 1-4"	7.65 " 10.20	7 " "	10 " "	15 " "

26. The purchaser shall be furnished complete copies of mill orders, and no material shall be rolled, nor work done, before the purchaser has been notified where the orders have been placed, so that he may arrange for the inspection.

27. The manufacturer shall furnish all facilities for inspecting and testing the weight and quality of all material at the mill where it is manufactured. He shall furnish a suitable testing machine for testing the specimens, as well as prepare the pieces for the machine, free of cost.

28. When an inspector is furnished by the purchaser to inspect material at the mills, he shall have full access, at all times, to all parts of mills where material to be inspected by him is being manufactured.

STANDARD SPECIFICATIONS FOR STEEL CASTINGS.*

1. Steel for castings may be made by the open-hearth, crucible or Bessemer process. Castings to be annealed unless otherwise specified. **Process of Manufacture.**

2. Ordinary castings, those in which no physical requirements are specified, shall not contain over 0.40 per cent. of carbon, nor over 0.08 per cent. of phosphorus. **Chemical Properties**

3. Castings which are subjected to physical test shall not contain over 0.05 per cent. of phosphorus, nor over 0.05 per cent. of sulphur.

4. Tested castings shall be of three classes: "HARD," "MEDIUM," and "SOFT." The minimum physical qualities required in each class shall be as follows: **Tensile Tests**

	Hard castings.	Medium castings.	Soft castings
Tensile strength, pounds per square inch	85,000	70,000	60,000
Yield point, pounds per square inch....	38,250	31,500	27,000
Elongation, per cent. in two inches....	15	18	22
Contraction of area, per cent.........	20	25	30

5. A test to destruction may be substituted for the tensile test, in the case of small or unimportant castings, by selecting three castings from a lot. This test shall show the material to be ductile and free from injurious defects, and suitable for the purposes intended. A lot shall consist of all castings from the same melt or blow, annealed in the same furnace charge. **Drop Test.**

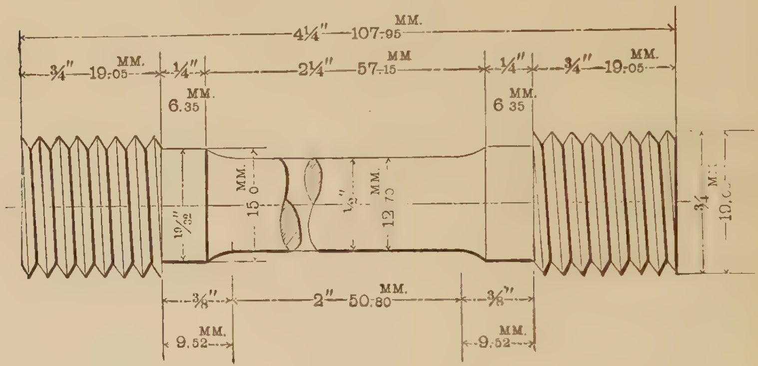
6. Large castings are to be suspended and hammered all over. No cracks, flaws, defects, nor weakness shall appear after such treatment. **Percussive Test.**

7. A specimen one inch by one-half inch (1″ x ½″) shall bend cold around a diameter of one inch (1″) without fracture on outside of bent portion, through an angle of 120° for "SOFT" castings, of 90° for "MEDIUM" castings. **Bending Test.**

8. The standard turned test specimen, one-half inch (½″) in diameter and two inch (2″) gauged length, shall be used to deter- **Test Piece for Tensile Test.**

*Adopted by letter-ballot of the Society on September 1, 1905.

mine the physical properties specified in paragraph No. 4. It is shown in the following sketch:



Number and Location of Specimens.

9. The number of standard test specimens shall depend upon the character and importance of the castings. A test piece shall be cut cold from a coupon to be molded and cast on some portion of one or more castings from each melt or blow or from the sink-heads (in case heads of sufficient size are used). The coupon or sink-head must receive the same treatment as the casting or castings, before the specimen is cut out, and before the coupon or sink-head is removed from the casting.

Test Piece for Bending.

10. One specimen for bending test one inch by one-half inch (1″ x ½″) shall be cut cold from the coupon or sink-head of the casting or castings as specified in paragraph No. 9. The bending test may be made by pressure, or by blows.

Yield Point.

11. The yield point specified in paragraph No. 4 shall be determined by the careful observation of the drop of the beam or halt in the gauge of the testing machine.

Sample for Chemical Analysis.

12. Turnings from the tensile specimen, drillings from the bending specimen, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in phosphorus and sulphur specified in paragraphs Nos. 2 and 3.

Finish.

13. Castings shall be true to pattern, free from blemishes, flaws or shrinkage cracks. Bearing surfaces shall be solid, and no porosity shall be allowed in positions where the resistance and

value of the casting for the purpose intended, will be seriously affected thereby.

14. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment. **Inspection.**

STANDARD SPECIFICATIONS FOR STEEL AXLES.*

Manufacture. 1. Steel for axles shall be made by the open-hearth process.

Chemical Properties. 2. There will be three classes of steel axles which shall conform to the following limits in chemical composition.

	Car and Tender Truck Axles. Per cent.	Driving and Engine Truck Axles. (Carbon Steel.) Per cent.	Driving and Engine Truck Axles. (Nickel Steel.) Per cent.
Phosphorus shall not exceed	0.06	0.06	0.04
Sulphur " " "	0.06	0.06	0.04
Manganese " " "	....	0.60	....
Nickel..................	....	....	3.0 to 4.0

Physical Properties. 3. For car and tender truck axles no tensile test shall be required.

4. The minimum physical qualities required in the two classes of driving and engine truck axles shall be as follows:

	Driving and Engine Truck Axles. (Carbon Steel.)	Driving and Engine Truck Axles. (Nickel Steel.)
Tensile strength, pounds per square inch .	80,000	80,000
Yield point, pounds per square inch	40,000	50,000
Elongation, per cent. in two inches	20	25
Contraction of area, per cent.	25	45

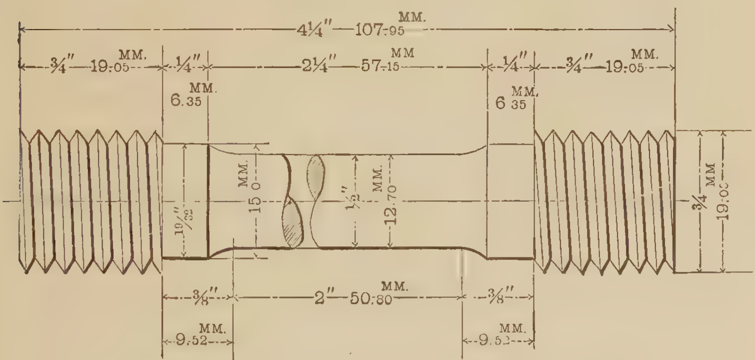
Drop Test. 5. One axle selected from each melt, when tested by the drop test described in paragraph No. 9, shall stand the number of blows at the height specified in the following table without rupture and without exceeding, as the result of the first blow, the deflection given. Any melt failing to meet these requirements will be rejected.

*Adopted by letter-ballot of the Society on September 1, 1905.

Diameter of Axle at Center. Inches.	Number of Blows.	Height of Drop. Feet.	Deflection. Inches.
4¼	5	24	8¼
4⅜	5	26	8¼
4 7/16	5	28½	8¼
4⅝	5	31	8
4¾	5	34	8
5⅜	5	43	7
5⅞	7	43	5½

6. Carbon steel and nickel steel driving and engine truck axles shall not be subject to the above drop test.

7. The standard turned test specimen one-half inch (½″) diameter and two inch (2″) gauged length, shall be used to determine the physical properties specified in paragraph No. 4. It is shown in the following sketch: **Test Pieces and Methods of Testing,**



8. For driving and engine truck axles one longitudinal test specimen shall be cut from one axle of each melt. The center of this test specimen shall be half-way between the center and outside of the axle. **Number and Location of Tensile Specimens.**

9. The points of supports on which the axle rests during tests must be three feet apart from center to center; the tup must weigh 1,640 pounds; the anvil, which is supported on springs, must weigh 17,500 pounds; it must be free to move in a vertical direction; the springs upon which it rests must be twelve in number, of the kind described on drawing; and the radius of supports and of the striking face on the tup in the direction of the axis of the axle must be five (5) inches. When an axle is tested it must be so **Drop Test Described.**

placed in the machine that the tup will strike it midway between the ends, and it must be turned over after the first and third blows, and when required, after the fifth blow. To measure the deflection after the first blow prepare a straight edge as long as the axle, by reinforcing it on one side, equally at each end, so that when t is laid on the axle, the reinforced parts will rest on the collars or ends of the axle, and the balance of the straight edge not touch the axle at any place. Next place the axle in position for test, lay the straight edge on it, and measure the distance from the straight edge to the axle at the middle point of the latter. Then after the first blow, place the straight edge on the now bent axle in the same manner as before, and measure the distance from it to that side of the axle next to the straight edge at the point farthest away from the latter. The difference between the two measurements is the deflection. The report of the drop test shall state the atmospheric temperature at the time the tests were made.

Yield Point. 10. The yield point specified in paragraph No. 4 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine.

Sample for Chemical Analysis. 11. Turnings from the tensile test specimen of driving and engine truck axles, or drillings taken midway between the center and outside of car, and tender truck axles, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether the melt is within the limits of chemical composition specified in paragraph No. 2.

Finish. 12. Axles shall conform in sizes, shapes and limiting weights to the requirements given on the order or print sent with it. They shall be made and finished in a workmanlike manner, and shall be free from all injurious cracks, seams or flaws. In centering, sixty (60) degree centers must be used, with clearance given at the point to avoid dulling the shop lathe centers.

Branding. 13. Each axle shall be legibly stamped with the melt number and initials of the maker at the places marked on the print or indicated by the inspector.

Inspection. 14. The inspector representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

STANDARD SPECIFICATIONS FOR STEEL FORGINGS.*

1. Steel for forgings may be made by the open-hearth, crucible or Bessemer process. **Manufacture.**

2. There will be four classes of steel forgings which shall conform to the following limits in chemical composition. **Chemical Properties.**

	Forgings of Soft or Low Carbon Steel. Per cent.	Forgings of Carbon Steel not Annealed. Per cent.	Forgings of Carbon Steel, Oil Tempered or Annealed. Per cent.	Locomotive Forgings. Per cent.	Forgings of Nickel Steel, Oil Tempered or Annealed. Per cent.
Phosphorus shall not exceed..	0.10	0.06	0.04	0.05	0.04
Sulphur " " " ..	0.10	0.06	0.04	0.05	0.04
Manganese " " " ..	....	....	....	0.60	....
Nickel....................	....	....	....	....	3.0 to 4.0

3. The minimum physical qualities required of the different sized forgings of each class shall be as follows **Physical Properties.**

	Tensile Strength. Pounds per square inch.	Yield Point. Pounds per square inch.	Elongation in 2". Per cent.	Contraction of Area. Per cent.
SOFT STEEL OR LOW CARBON STEEL.				
For solid or hollow forgings, no diameter or thickness of section to exceed 10"..........	58,000	29,000	28	35
CARBON STEEL NOT ANNEALED.				
For solid or hollow forgings, no diameter or thickness of section to exceed 10"..........	75,000	37,500	18	30
CARBON STEEL ANNEALED.		Elastic limit.		
For solid or hollow forgings, no diameter or thickness of section to exceed 10"..........	80,000	40,000	22	35
For solid forgings, no diameter to exceed 20" or thickness of section 15"..................	75,000	37,500	23	35
For solid forgings, over 20" diameter.........	70,000	35,000	24	30
CARBON STEEL, OIL TEMPERED.				
For solid or hollow forgings, no diameter or thickness of section to exceed 3"...........	90,000	55,000	20	45

*Adopted by letter-ballot of the Society on September 1, 1905.

	Tensile Strength.	Elastic Limit.	Elongation in 2″.	Contraction of Area.
	Pounds per square inch.		Per cent.	
CARBON STEEL, OIL TEMPERED.				
For solid forgings of rectangular sections not exceeding 6″ in thickness or hollow forgings, the walls of which do not exceed 6″ in thickness	85,000	50,000	22	45
For solid forgings of rectangular sections not exceeding 10″ in thickness or hollow forgings, the walls of which do not exceed 10″ in thickness	80,000	45,000	23	40
LOCOMOTIVE FORGINGS.	80,000	40,000	20	25
NICKEL STEEL ANNEALED.				
For solid or hollow forgings, no diameter or thickness of section to exceed 10″	80,000	50,000	25	45
For solid forgings, no diameter to exceed 20″ or thickness of section 15″	80,000	45,000	25	45
For solid forgings, over 20″ diameter	80,000	45,000	24	40
NICKEL STEEL, OIL TEMPERED.				
For solid or hollow forgings, no diameter or thickness of section to exceed 3″	95,000	65,000	21	50
For solid forgings of rectangular sections not exceeding 6″ in thickness or hollow forgings, the walls of which do not exceed 6″ in thickness	90,000	60,000	22	50
For solid forgings of rectangular sections not exceeding 10″ in thickness or hollow forgings, the walls of which do not exceed 10″ in thickness	85,000	55,000	24	45

Bending Test. 4. A specimen one inch by one-half inch (1″ x ½″) shall bend cold 180° without fracture on outside of bent portion, as follows:

Around a diameter of ½″, for forgings of soft steel,

Around a diameter of 1½″, for forgings of carbon steel not annealed,

Around a diameter of 1½″, for forgings of carbon steel annealed, if 20″ in diameter or over,

Around a diameter of 1″, for forgings of carbon steel annealed, if under 20″ diameter,

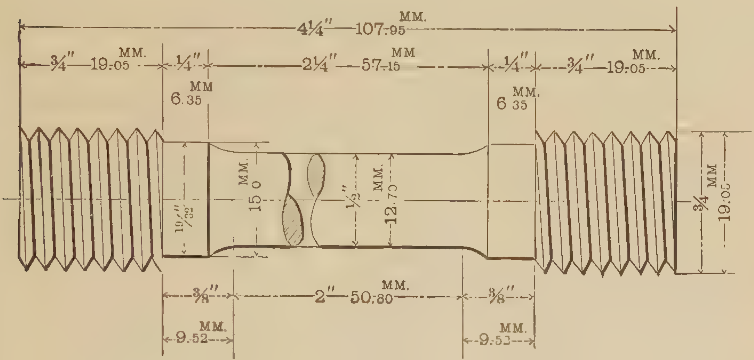
Around a diameter of 1″ for forgings of carbon steel oil-tempered,

Around a diameter of ½″, for forgings of nickel steel annealed,

Around a diameter of 1″, for forgings of nickel steel oil-tempered.

For locomotive forgings no bending test will be required.

5. The standard turned test specimen, one-half inch ($\frac{1}{2}''$) diameter and two inch ($2''$) gauged length, shall be used to determine the physical properties specified in paragraph No. 3. It is shown in the following sketch. **Test Pieces and Methods of Testing.**



6. The number and location of test specimens to be taken from a melt, blow, or a forging shall depend upon its character and importance and must therefore be regulated by individual cases. The test specimens shall be cut cold from the forging or full-sized prolongation of same parallel to the axis of the forging and half-way between the center and outside, the specimens to be longitudinal, *i. e.*, the length of the specimen to correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged or bored, the specimen shall be taken within the finished section prolonged, half-way between the inner and outer surface of the wall of the forging. **Number and Location of Tensile Specimens.**

7. The specimen for bending test one inch by one-half inch ($1'' \times \frac{1}{2}''$) shall be cut as specified in paragraph No. 6. The bending test may be made by pressure or by blows. **Test Specimen for Bending.**

8. The yield point specified in paragraph No. 3 shall be determined by the careful observation of the drop of the beam, or halt in the gauge of the testing machine. **Yield Point.**

9. The elastic limit specified in paragraph No. 3 shall be deter- **Elastc Limit.**

mined by means of an extensometer, which is to be attached to the test specimen in such manner as to show the change in rate of extension under uniform rate of loading, and will be taken at that point where the proportionality changes.

Sample for Chemical Analysis.

10. Turnings from the tensile specimen or drillings from the bending specimen or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in chemical composition specified in paragraph No. 2.

FINISH.

11. Forgings shall be free from cracks, flaws, seams or other injurious imperfections, and shall conform to dimensions shown on drawings furnished by the purchaser, and be made and finished in a workmanlike manner.

INSPECTION.

12. The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture, prior to shipment.

REPORT OF COMMITTEE B ON STANDARD SPECIFICATIONS FOR CAST IRON AND FINISHED CASTINGS.

At the last Annual Meeting Committee B submitted proposed Standard Specifications for the following products:

1. Foundry Pig Iron.
2. Cast Iron Pipe and Special Castings.
3. Locomotive Cylinders.
4. Cast Iron Car Wheels.
5. Malleable Castings.
6. Gray Iron Castings.

At that meeting it was decided to refer the specifications for Foundry Pig Iron, Cast Iron Pipe and Special Castings, Locomotive Cylinders and Malleable Castings to letter-ballot of the Society, in the original form as submitted by the Committee, or with slight amendments. The letter-ballot on these specifications resulted favorably and they are accordingly recognized among the Standard Specifications of the Society.

The proposed Standard Specifications for Cast Iron Car Wheels and Gray Iron Castings were discussed and referred back to the Committee. These specifications are herewith submitted for such action as the Society may see fit to take.

The specifications for Cast Iron Car Wheels embody certain modifications concerning which Dr. Charles B. Dudley, Chairman of the sub-committee, charged with their preparation, writes as follows:

"In connection with the proposed Standard Specifications for Cast Iron Car Wheels in their revised form as herewith submitted, it may be said that there were three items in these specifications as presented last year, which apparently needed further investigation. One was the question of weights, another the question of the drop, and a third, was the method of stating the variation in weight allowable. The specifications as submitted to you embody the criticisms that were made. The weights are made round figures, and the variation is stated to be two per cent. either way. Some changes have been made in the height of drop in accordance with a series of experiments made during the past year on wheels of the weights given in the specifications, and the weight

of the drop has been increased from 140 to 200 pounds, in accordance with the same experiments. The specifications otherwise stand as drawn last year."

The Specifications for Gray Iron Castings are submitted without change for reasons which appear in the following communication from Mr. Henry Souther, Chairman of the sub-committee, responsible for the same:

"As chairman of the sub-committee on Specifications for Gray Iron Castings, the writer begs to make the following report, following the resolution passed at the meeting on June 17, 1904:

"At the last Annual Meeting the Specifications for Gray Iron Castings were referred back to the committee for further study, with instructions to report their conclusions.

"Since that meeting some study has been given the matter by its members, notably Professor Lanza. His investigations found that the time element was sufficiently accurate for the purposes of this test, and he has, therefore, withdrawn all objections on this score.

"Another very pertinent criticism was to the effect that no cast iron tension test should be recognized that had not been made with the best approved ball joints. This provision is not found in the specifications because no well recognized ball joint has been standardized. There are many in use that are undoubtedly good, but they differ greatly in their efficiency, and are not all sufficiently alike in their behavior to produce first-rate results. If such a standard set of ball joints can be devised, then the use of that particular ball joint might well be incorporated in the specifications.

"The round test bars are giving uniformly good results in this laboratory and have created no friction in the foundries called upon to cast them, the only difficulty in connection with them being that the foundrymen feel called upon to finish them in some way, either by tumbling or grinding. Also the full importance of closely following the casting directions is not grasped by the average foundryman.

"It is certain that if the specifications, as printed, are followed and lived up to by all concerned, the quality of such castings may be controlled by them, and that being the object of these specifications, it would seem to your committee that they fulfill the purpose for which they were intended."

The proposed Standard Specifications for Cast Iron Car Wheels and Gray Iron Castings are appended to this report.

Respectfully submitted on behalf of the Committee,

WALTER WOOD, *Chairman.*

RICHARD MOLDENKE, *Secretary.*

APPENDIX I.

PROPOSED STANDARD SPECIFICATIONS FOR CAST-IRON CAR WHEELS.*

Chemical Properties.

The wheels furnished under this specification must be made from the best materials, and in accordance with the best foundry methods. The following pattern analysis is given for information, as representing the chemical properties of a good cast-iron wheel. Successful wheels, varying in some of the constituents quite considerably from the figures given, may be made:

Total carbon	3.50 per cent.
Graphitic carbon	2.90 "
Combined carbon	0.60 "
Silicon	0.70 "
Manganese	0.40 "
Phosphorus	0.50 "
Sulphur	0.08 "

1. Wheels will be inspected and tested at the place of manufacture.

2. All wheels must conform in general design and in measurements to drawings, which will be furnished, and any departure from the standard drawing must be by special permission in writing, and manufacturers wishing to deviate from the standard dimensions must submit duplicate drawings showing the proposed changes, which must be approved.

Drop Tests.

3. The following table gives data as to weight and tests of various kinds of wheels for different kinds of cars and service:

Wheel		33-inch diameter Frgt. and Pass. cars.			36-inch diameter.	
Kind of service		60,000 lbs. capacity and less.	70,000 lbs. capacity.	100,000 lbs. capacity.	Passenger Cars.	Locomotive Tenders.
Number		1	2	3	4	5
Weight	Desired	600	650	700	700 lbs.	750 lbs.
	Variation	Two per cent. either way.				
Height of drop, ft.		9	12	12	12	12
Number of blows		10	10	12	12	14

*Adopted by letter-ballot of the Society on September 1, 1905.

Marking. 4. Each wheel must have plainly cast on the outside plate the name of the maker and place of manufacture. Each wheel must also have cast on the inside double plate the date of casting and a serial foundry number. The manufacturer must also provide for the guarantee mark, if so required by the contract. No wheel bearing a duplicate number, or a number which has once been passed upon, will be considered. Numbers of wheels once rejected will remain unfilled. No wheel bearing an indistinct number or date, or any evidence of an altered or defaced number will be considered.

Measures. 5. All wheels offered for inspection must have been measured with a standard tape measure and must have the shrinkage number stenciled in plain figures on the inside of the wheel. The standard tape measure must correspond in form and construction to the "Wheel Circumference Measure" established by the Master Car Builders' Association in 1900. The nomenclature of that measure need not, however, be followed, it being sufficient if the graduating marks indicating tape sizes are one-eighth of an inch apart. Any convenient method of showing the shrinkage or stencil number may be employed. Experience shows that standard tape measures elongate a little with use, and it is essential to have them frequently compared and rectified. When ready for inspection, the wheels must be arranged in rows according to shrinkage numbers, all wheels of the same date being grouped together. Wheels bearing dates more than thirty days prior to the date of inspection will not be accepted for test, except by permission. For any single inspection and test only wheels having three consecutive shrinkage or stencil numbers will be considered. The manufacturer will, of course, decide what three shrinkage or stencil numbers he will submit in any given lot of 103 wheels offered, and the same three shrinkage or stencil numbers need not be offered each time.

Finish. 6. The body of the wheels must be smooth and free from slag and blowholes, and the hubs must be solid. Wheels will not be rejected because of drawing around the center core. The tread and throat of the wheels must be smooth, free from deep and irregular wrinkles, slag, sand wash, chill cracks or swollen rims, and be free from any evidence of hollow rims, and the throat and thread must be practically free from sweat.

7. Wheels tested must show soft, clean, gray iron, free from defects, such as holes containing slag or dirt more than one-quarter of an inch in diameter, or clusters of such holes, honey-combing of iron in the hub, white iron in the plates or hub, or clear white iron around the anchors of chaplets at a greater distance than one-half of an inch in any direction. The depth of the clear white iron must not exceed seven-eighths of an inch at the throat and one inch at the middle of the tread, nor must it be less than three-eighths of an inch at the throat or any part of the tread. The blending of the white iron with the gray iron behind must be without any distinct line of demarcation, and the iron must not have a mottled appearance in any part of the wheel at a greater distance than one and five-eighths inches from the tread or throat. The depth of chill will be determined by inspection of the three test wheels described below, all test wheels being broken for this purpose, if necessary. If one only of the three test wheels fails in limits of chill, all the lot under test of the same shrinkage or stencil number will be rejected and the test will be regarded as finished so far as this lot of 103 wheels is concerned. The manufacturer may, however, offer the wheels of the other two shrinkage or stencil numbers, provided they are acceptable in other respects as constituents of another 103 wheels for a subsequent test. If two of the three test wheels fail in limits of chill, the wheels in the lot of 103 of the same shrinkage or stencil number as these two wheels will be rejected, and, as before, the test will be regarded as finished so far as this lot of 103 wheels is concerned. The manufacturer may, however, offer the wheels of the third shrinkage or stencil number, provided they are acceptable in other respects, as constituents of another 103 wheels for a subsequent test. If all three test wheels fail in limits of chill, of course the whole hundred will be rejected. **Material and Chill.**

8. The manufacturer must notify when he is ready to ship not less than 100 wheels; must await the arrival of the Inspector; must have a car, or cars, ready to be loaded with the wheels, and must furnish facilities and labor to enable the Inspector to inspect, test, load and ship the wheels promptly. Wheels offered for inspection must not be covered with any substance which will hide defects. **Inspection and Shipping.**

9. A hundred or more wheels being ready for test, the Inspec-

tor will make a list of the wheel numbers, at the same time examining each wheel for defects. Any wheels which fail to conform to specifications by reason of defects must be laid aside, and such wheels will not be accepted for shipment. As individual wheels are rejected, others of the proper shrinkage, or stencil number, may be offered to keep the number good.

Retaping. 10. The Inspector will retape not less than 10 per cent of the wheels offered for test, and if he finds any showing wrong tape-marking, he will tape the whole lot and require them to be restenciled, at the same time having the old stencil marks obliterated. He will weigh and make check measurements of at least 10 per cent of the wheels offered for test, and if any of these wheels fail to conform to the specification, he will weigh and measure the whole lot, refusing to accept for shipment any wheels which fail in these respects.

Drop Tests. 11. Experience indicates that wheels with higher shrinkage or lower stencil numbers are more apt to fail on thermal test; more apt to fail on drop test, and more apt to exceed the maximum allowable chill than those with higher stencil or lower shrinkage numbers; while, on the other hand, wheels with higher stencil or lower shrinkage numbers are more apt to be deficient in chill. For each 103 wheels apparently acceptable, the Inspector will select three wheels for test—one from each of the three shrinkage or stencil numbers offered. One of these wheels chosen for this purpose by the Inspector must be tested by drop test as follows: The wheel must be placed flange downward in an anvil block weighing not less than 1,700 pounds, set on rubble masonry two feet deep and having three supports not more than five inches wide for the flange of the wheel to rest on. It must be struck centrally upon the hub by a weight of 200 pounds, falling from a height as shown in the table on page 1. The end of the falling weight must be flat, so as to strike fairly on the hub, and when by wear the bottom of the weight assumes a round or conical form, it must be replaced. The machine for making this test is shown on drawings which will be furnished. Should the wheel stand without breaking in two or more pieces, the number of blows, shown in the above table, the one hundred wheels represented by it will be considered satisfactory as to this test. Should it fail, the whole hundred will be rejected.

12. The other two test wheels must be tested as follows: The wheels must be laid flange down in the sand, and a channelway one and one-half inches in width at the center of the tread and four inches deep must be molded with green sand around the wheel. The clean tread of the wheel must form one side of this channelway, and the clean flange must form as much of the bottom as its width will cover. The channelway must then be filled to the top from one ladle with molten cast iron, which must be poured directly into the channelway without previous cooling or stirring, and this iron must be so hot, when poured, that the ring which is formed when the metal is cold shall be solid or free from wrinkles or layers. Iron at this temperature will usually cut a hole at the point of impact with the flange. In order to avoid spitting during the pouring, the tread and inside of the flange during the thermal test should be covered with a coat of shellac; wheels which are wet or which have been exposed to snow or frost may be warmed sufficiently to dry them or remove the frost before testing, but under no circumstances must the thermal test be applied to a wheel that in any part feels warm to the hand. The time when pouring ceases must be noted, and two minutes later an examination of the wheel under test must be made. If the wheel is found broken in pieces, or if any crack in the plates extends through or into the tread, the test wheel will be regarded as having failed. If both wheels stand, the whole hundred will be accepted as to this test. If both fail, the whole hundred will be rejected. If one only of the thermal test wheels fails, all of the lot under test of the same shrinkage or stencil number will be rejected, and the test will be regarded as finished, so far as this lot of wheels is concerned. The manufacturer may, however, offer the wheels of the other two shrinkage or stencil numbers, provided they are acceptable in other respects, as constituents of another 103 wheels for a subsequent test. **Thermal Test.**

13. All wheels which pass inspection and test will be regarded as accepted, and may be either shipped or stored for future shipment, as arranged. It is desired that shipments should be, as far as possible, in lots of 100 wheels. In all cases the Inspector must witness the shipment, and he must give, in his report, the numbers of all wheels inspected and the disposition made of them. **Storing and Shipping.**

Rejections. 14. Individual wheels will be considered to have failed and will not be accepted or further considered, which,

First. Do not conform to standard design and measurement.

Second. Are under or over weight.

Third. Have the physical defects described in Section 6.

Rejections. 15. Each 103 wheels submitted for test will be considered to have failed and will not be accepted or considered further, if,

First. The test wheels do not conform to Section 7, especially as to limits of white iron in the throat and tread and around chaplets.

Second. One of the test wheels does not stand the drop test as described in Section 11.

Third. Both of the two test wheels do not stand the thermal test as described in Section 12.

APPENDIX II.

PROPOSED STANDARD SPECIFICATIONS FOR GRAY IRON CASTINGS.*

1. Unless furnace iron is specified, all gray castings are understood to be made by the cupola process. **Process of Manufacture.**

2. The sulphur contents to be as follows: **Chemical Properties.**

Light castings	not over	0.08 per cent.
Medium castings	"	0.10 "
Heavy casting	"	0.12 "

3. In dividing castings into light, medium and heavy classes, the following standards have been adopted: **Classification**

Castings having any section less than ½-inch thick shall be known as *light castings.*

Castings in which no section is less than 2 inches thick shall be known as *heavy castings.*

Medium castings are those not included in the above classification.

4. *Transverse Test.* The minimum breaking strength of the "Arbitration Bar" under transverse load shall be not under: **Physical Properties.**

Light castings	2,500 lbs.
Medium castings	2,900 "
Heavy castings	3,300 "

In no case shall the deflection be under .10 of an inch.

Tensile Test. Where specified, this shall not run less than:

Light castings	18,000 lbs. per sq. in.
Medium castings	21,000 " " "
Heavy castings	24,000 " " "

5. The quality of the iron going into castings under specification shall be determined by means of the "Arbitration Bar." This is a bar 1¼ inches in diameter and 15 inches long. It shall be prepared as stated further on and tested transversely. The tensile test is not recommended, but in case it is called for, the bar as shown in Fig. 1, and turned up from any of the broken pieces **"Arbitration Bar"**

*Adopted by letter-ballot of the Society on September 1, 1905.

of the transverse test shall be used. The expense of the tensile test shall fall on the purchaser.

Number of Test Bars. 6. Two sets of two bars shall be cast from each heat, one set from the first and the other set from the last iron going into the castings. Where the heat exceeds twenty tons, an additional set of two bars shall be cast for each twenty tons or fraction thereof above this amount. In case of a change of mixture during the heat, one set of two bars shall also be cast for every mixture other than the regular one. Each set of two bars is to go into a single

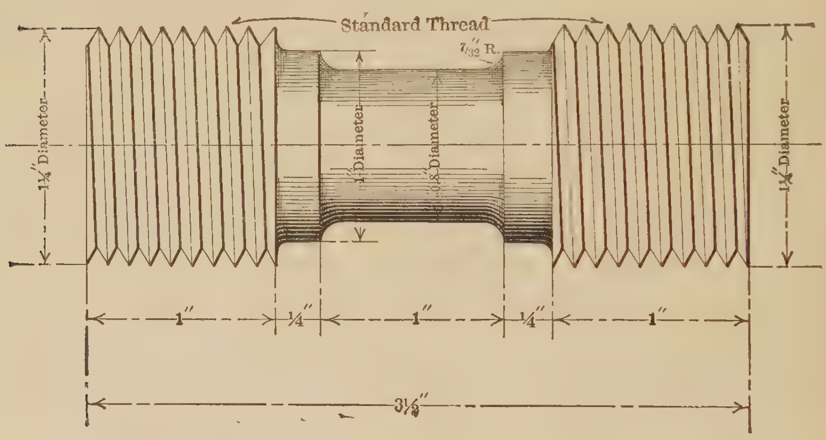


FIG. 1.—ARBITRATION TEST BAR. TENSILE TEST PIECE.

mold. The bars shall not be rumbled or otherwise treated, being simply brushed off before testing.

Method of Testing. 7. The transverse test shall be made on all the bars cast, with supports 12 inches apart, load applied at the middle, and the deflection at rupture noted. One bar of every two of each set made must fulfill the requirements to permit acceptance of the castings represented.

Mold for Test Bar. 8. The mold for the bars is shown in Fig. 2. The bottom of the bar is 1–16 of an inch smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask is to be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of one to twelve bitumi-

nous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled.

9. The rate of application of the load shall be from 20 to 40 seconds for a deflection of 0.10 inch. **Speed of Testing.**

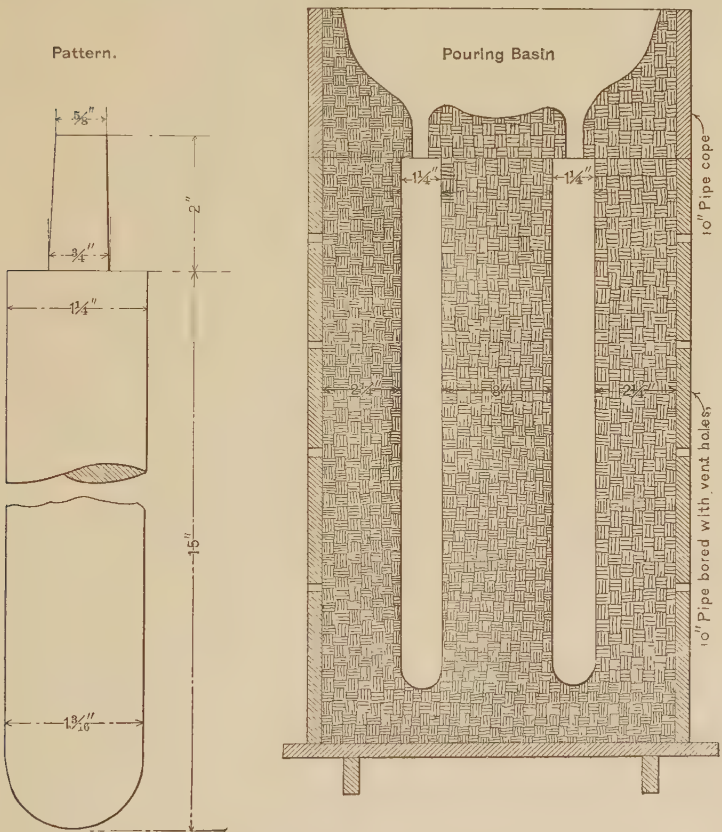


FIG. 2.—MOLD FOR ARBITRATION TEST BAR.

10. Borings from the broken pieces of the "Arbitration Bar" shall be used for the sulphur determinations. One determination for each mold made shall be required. In case of dispute, the standards of the American Foundrymen's Association shall be used for comparison. **Samples for Analysis.**

Finish. 11. Castings shall be true to pattern, free from cracks, flaws and excessive shrinkage. In other respects they shall conform to whatever points may be specially agreed upon.

Inspection. 12. The Inspector shall have reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall, as far as possible, be made at the place of manufacture prior to shipment.

REPORT OF COMMITTEE C ON STANDARD SPECIFICATIONS FOR CEMENT.

The Committee on Standard Specifications for Cement desires to present the following report:

The Standard Specifications for Cement which were reported by your Committee at the last annual meeting were formally adopted by the Society by letter ballot on November 14, 1904. The interval which has since elapsed is not considered by your committee to be of sufficient length for a thorough trial of the specifications and it has been decided to postpone the consideration of any changes in the specifications for the present.

Believing that the steps which led to the final adoption of the standard specifications for cement are, and will be, of increasing interest, the Committee presents the following statement as a matter of record:

With the rapid development of the cement industry the attainment of a standard of specifications has been earnestly sought. The report of the Committee of the American Society of Civil Engineers, on January 7, 1885, was the first step in this country in this direction. This report, however, within a very few years became too elastic and indefinite to serve the purpose.

In 1896, at the suggestion of Mr. Richard L. Humphrey, a series of editorials appeared in the *Engineering Record* calling attention to the inadequacy of the 1885 rules and urging the appointment of a new committee to revise them. Following this a resolution was presented by Mr. Edward P. North at a meeting of the American Society of Civil Engineers, held November 4, 1896, requesting the Board of Direction to report on the advisability of appointing a committee to report on "The Proper Manipulation of the Tests of Cement." The Board reported at the annual meeting of the Society on January 20, 1897, and was instructed to issue a letter ballot. This vote was canvassed, and on July 1, 1897, the board appointed a committee, consisting of Messrs. George F. Swain; Alfred Noble, George S. Webster, W. B. W. Howe, L. C. Sabin, O. M. Carter and H. M. York; the two members last named subsequently resigned.

This Committee organized with Prof. George F. Swain as Chair-

man and Mr. H. M. York as Secretary. A circular was prepared and widely circulated, and at the annual meeting in January, 1900, a progress report was presented, giving a summary of the answers received.

At the annual meeting, held on January 10, 1901, the Committee was authorized to increase its membership to nine, and, in accordance therewith appointed Messrs. Spencer B. Newberry, Clifford Richardson, Richard L. Humphrey and F. H. Lewis.

This Committee organized by the election of Prof. George F. Swain, Chairman, and Mr. Richard L. Humphrey, Secretary. On the retirement of Prof. Swain from the chairmanship, under pressure of personal affairs, Mr. George S. Webster was elected in his place. The Committee presented to the Society a Progress Report on Uniform Tests of Cement on January 21, 1903.

Efforts were made in 1901 by the American members of the various committees on cement of the International Association for Testing Materials to secure international co-operation in the adoption of standard specifications for cement. This effort came to naught because there were no uniform methods for testing cement and because also of the inability to agree on such methods.

On June 8, 1901, the Board of Engineer Officers U. S. A., appointed by the authority of the Secretary of War, presented a report on Testing Hydraulic Cements, to which were appended Standard Specifications for both natural and Portland cements.

At the annual meeting of the American Society for Testing Materials, held on June 15, 1902, the Executive Committee was authorized to appoint a Committee to report on Standard Specifications for Cement, and in accordance therewith named Messrs. Robert W. Lesley, Booth, Garrett and Blair, A. W. Dow, Edward M. Hagar, Richard L. Humphrey, Lathbury and Spackman, Andreas Lundteigen, Charles F. McKenna, W. W. Maclay, Spencer B. Newberry, J. M. Porter, Clifford Richardson and George F. Swain, with power to increase the membership subject to the approval of the Executive Committee.

The Committee assembled at the call of Mr. Robert W. Lesley, Member of the Executive Committee and Temporary Chairman, on October 31st, 1902, and organized by the election of Prof. George F. Swain, Chairman, Mr. George S. Webster, Vice-Chairman, and Mr. Richard L. Humphrey, Secretary.

The Committee increased its number by the addition of the following members: Messrs. T. J. Brady, C. W. Boynton, Spencer Cosby, L. Henry Dumary, A. F. Gerstell, William H. Harding, F. H. Lewis, John B. Lober, Charles A. Matcham, Alfred Noble, H. W. Parkhurst, Joseph T. Richards, L. C. Sabin, H. J. Seaman, H. S. Voorhees, W. J. Wilgus, George S. Webster, H. G. Kelly, Vice-president American Railway Engineering and Maintenance of Way Association, and W. S. Eames, President American Institute of Architects. Messrs. Alfred Noble, H. W. Parkhurst and W. J. Wilgus subsequently resigned from the Committee, as did Mr. F. H. Bainbridge who was appointed to succeed Mr. Parkhurst. The Committee postponed further action pending the report of the Committee on Uniform Tests of Cement of the American Society of Civil Engineers.

On February 4, 1903, the Committee adopted as a basis for its work the report of the Committee on Uniform Tests of Cement.

In order to obtain data to aid in drafting Standard Specifications and to test the value of the methods recommended, the Committee sent four samples of natural and five samples of Portland Cement to some thirty prominent laboratories engaged in testing cement with the request that they be tested in accordance with these methods. The results of these tests were collated, and in accordance with the instructions of the Committee tentative specifications were prepared by the Secretary, Mr. Richard L. Humphrey. These were considered on December 3, 1903, amended and approved March 29, 1904, and adopted by the Committee by letter ballot, June 11, 1904. These specifications were approved by the American Society for Testing Materials at its annual meeting, June 17, 1904, and adopted by letter ballot of the Society, November 14, 1904.

On December 9, 1902, the Association of American Portland Cement Manufacturers appointed a Committee on Standard Specifications for Cement, consisting of Messrs. W. W. Maclay, A. F. Gerstell, D. Millen, B. S. Dunn, T. M. Righter. This Committee was succeeded on January 12, 1904, by the appointment of Messrs. W. W. Maclay, Chairman; A. F. Gerstell, W. H. Harding, S. B. Newberry, Charles A. Matcham, H. J. Seaman and Charles F. Wade. The latter committee recommended the

above specifications to the Association, and they were adopted on June 16, 1904.

The Committee on Masonry of the American Railway Engineering and Maintenance of Way Association presented specifications for Portland and natural cement, which were adopted by the Association at the annual convention held March 19, 1903, and recommended as provisional standard specifications. At the convention held in March, 1904, no further action was taken in view of the Association having been requested to send a representative to serve on the Committee on Standard Specifications for Cement. Upon the recommendation of the same Committee the Association, in place of the provisional specification above referred to, adopted the standard specifications of the American Society for Testing Materials, on March 21, 1905.

These reports on Uniform Tests of Cement and Standard Specifications for Cement are the result of over six years' labor of a representative body covering every field from the manufacturer to the consumer. The various committees are still in existence and will from time to time recommend such changes as are found by experience to be desirable, thus gradually perfecting the specifications as a whole. In the meantime by the adoption of these specifications a standard of excellence is set which will enable the manufacturer to concentrate his efforts in operating his plant so as to produce uniformly the grade of cement required and at a minimum cost to the consumer.

Submitted on behalf of the Committee:

GEORGE F. SWAIN, *Chairman.*
GEORGE S. WEBSTER, *Vice-Chairman.*
RICHARD L. HUMPHREY, *Secretary.*

Committee:

George F. Swain.
George S. Webster.
Richard L. Humphrey.
Booth, Garrett & Blair.
C. W. Boynton.
Spencer Cosby.
A. W. Dow.
L. Henry Dumary.
A. F. Gerstell.
Edward M. Hagar.
W. H. Harding.
Henry S. Spackman Engineering Co.
Olaf Hoff.
Robert W. Lesley.
John B. Lober.
Andreas Lundteigen.
Charles F. McKenna.
W. W. Maclay.
Charles A. Matcham.
Spencer R. Newberry.
J. M. Porter.
Joseph T. Richards.
Clifford Richardson.
L. C. Sabin.
Harry J. Seaman.
F. H. Lewis.
S. S. Voorhees.

American Institute of Architects, W. S. Eames, *President.*
American Railway Engineering and Maintenance of Way Association, H. G. Kelly, *President.*

REPORT OF COMMITTEE E ON PRESERVATIVE COATINGS FOR IRON AND STEEL.

Your Committee, in presenting this Annual Report, feels that much progress has been made during the last year. Up to this time, the work of the Committee has, of necessity, been that of clearing ground. Now, it feels that its work is fully formulated and properly organized. In the report of this Committee presented in 1903 to the Sixth Annual Meeting of the Society, the following statement occurs:

"It is further considered that the function of this Committee is not to specify any covering or coverings as protective, but to specify tests which coatings must stand to assure maximum efficiency."

This is the position of the Committee to-day. It is not prepared, and never expects to be prepared, to recommend any particular paint for any particular exposure. It is seeking to discover methods of conducting laboratory tests which will indicate the protective value of a paint under certain known conditions of exposure. Furthermore, it is not willing to recommend specifically any laboratory test whose value has not been demonstrated. The value of a laboratory test depends upon the degree to which it corresponds in its results with actual exposure tests. Your Committee, therefore, has provided sub-committees whose duties are to consider the various phases of this subject. These sub-committees were appointed after a meeting of this Committee (E) in Philadelphia in December last. The titles of these sub-committees, stated in logical order, and their personnel are as follows:

On Standard Methods of Conducting Field Tests:

W. A. Polk, *Chairmau.*
L. H. Barker.
Malcolm McNaughton.

On Standard Methods of Conducting Service Tests:
G. W. Thompson, *Chairman*:
W. A. Aiken.
Robert Job.
A. H. Sabin.
J. F. Walker.
On the Permeability of Paint Films:
C. B. Dudley, *Chairman*.
A. H. Sabin.
S. S. Voorhees.
On Permanency of Paint Films:
Malcolm McNaughton, *Chairman*.
A. W. Dow.
C. B. Dudley.
Robert Job.
G. W. Thompson.
On Preparation of Iron and Steel Surfaces for Painting:
J. W. Whitehead, Jr., *Chairman*.
W. A. Polk.
Max H. Wickhorst.

The idea is that the service tests act as a check on the field tests; that laboratory tests as to permeability should be accepted as of value only when found to be in accord with the field and service tests; and that the permanency of a film in its impermeability and other protective qualities should throw light on the results obtained by field and service tests.

The reports of these sub-committees follow.

S. S. VOORHEES,
Chairman.

REPORT OF SUB-COMMITTEE ON STANDARD METHODS OF CONDUCTING FIELD TESTS.

In presenting this report, we beg to make the following recommendation:

The scope and purpose of the Committee, as we understand it, is to suggest a series of tests which may be carried on by the General Committee for the purpose of classifying such paints as may come under the notice of engineers, architects, railroad

officials and others who may be interested in protective coatings for steel; these tests to be made on the following structures:—Tunnel sections, as the New York subway, railroad bridges exposed to action of locomotive gases, railway bridges not so exposed, highway city bridges and viaducts, highway country bridges and viaducts, elevated railroad structures, the New East River bridge over Blackwell's Island, and the Manhattan bridge, round houses and terminal sheds, gas holders, metal sidings on warehouses, piers, and all varieties of marine painting excepting bottoms.

In outlining a test on any one of these different structures, the committee would suggest, for instance, that a section, one-eighth of a mile in length be taken in a tunnel; that fifty paint manufacturers be allowed to be represented; and that each manufacturer furnish the material that he wishes to have applied for the purpose of protecting the steel exposed in the tunnel. The manufacturer shall make a deposit of a sufficient amount of money to have the surface prepared for painting and to have the paint analyzed by two reputable chemists. They may apply the paint themselves or they may allow it to be applied under the supervision of a committee which shall be appointed to take charge of the tests. There shall be a director of tests, who shall be appointed by Committee E.

At the time of application, samples of each paint shall be taken by the chemists on the ground, under the eye of the director of tests, the manufacturer being represented. There shall be three quart samples taken from original package, the same to be put in clean containers and shall be sealed in the presence of the director of tests. One of these samples shall be given to each chemist, and the third shall remain in the possession of the Society for the purpose of future identification. The Committee must have duplicate samples of all paints tested for the purpose of identification. The analyses of the various paints shall be made by the chemists appointed by the Committee, and such analyses shall go into the possession of The American Society for Testing Materials.

The application of the paint shall be made under the direct observation of the director of tests and the committee. This committee shall be called "The Committee on Field Tests" and

shall be appointed by Committee E. Proper records of the location of the various paints tested shall be kept by the Committee on Tests. At least one week shall elapse between the application of each coat of paint. All the paints should be applied within the same week if possible.

The Committee on Tests shall be continued during the course of the tests which may last for five (5) years, or indefinitely. Vacancies that may occur shall be filled by Committee E, and the Committee on Field Tests shall make periodical reports of the results of the inspection of the paints to Committee E. The consensus of such reports shall be printed in the Annual Proceedings of the Society.

A set of rules shall be formulated for procedure in making the tests, and a copy of the rules shall be forwarded to each manufacturer upon inviting him to participate in the tests. The Committee on Field Tests shall have full authority to make rules in regard to the time of application, and the condition of application under which each paint shall be applied.

The present Committee upon Investigation of Field Tests, as now constituted, has three members; it should have no less than five with a quorum of three, who shall have power to carry on the work of the Committee.

There will be difficulty, of course, upon smaller structures in apportioning a large amount of surface, or apportioning a full size member to each manufacturer who wishes to submit a sample for test. Undoubtedly, this question will have to be studied from a thoroughly practical standpoint before it is taken up.

The Committee has been successful in interesting several representative people in this matter of tests. We do not apprehend any difficulty in securing structures upon which to carry on our investigation.

W. A. POLK,
Chairman.

Report of Sub-Committee on Standard Methods of Conducting Service Tests.

Method of Preparing Painted Plates for Exposure Tests Under Service Conditions.

All service tests should be conducted in sets, so that the results obtained from each set of tests stand in a definite relation to each other, and are only to be compared with the results obtained from another set of service tests relatively. Each set of service tests should be exposed under conditions which are as nearly identical for each member of the set as possible.

Take a sufficient number of sheets of steel, if possible from the same heat, and preferably what is known commercially as "pickled and cold-rolled steel." These sheets of steel should be uniform in size and thickness, preferably No. 10 steel (about $\frac{1}{8}''$ in thickness) 36″ long x 24″ wide. If "pickled and cold-rolled steel" is not used, steel from a uniform lot is to be cleaned and pickled, as follows:

Dip the plates, if at all greasy, in a hot 10 per cent. caustic soda solution, then in hot water, then for a time uniform for each plate (say 10 minutes) in hot 10 per cent. sulphuric acid, then in hot water, then in hot 10 per cent. carbonate of soda solution, then rinse well in hot water and until the absence of H_2SO_4 or Na_2CO_3 is indicated by failure to secure a precipitate in the wash waters by the addition of $Ba\ Cl_2$ solution, and immediately dry in an oven; while hot, pack and dry in powdered caustic lime until wanted for painting; remove all lime dust carefully by a stiff brush before painting. These treating and washing solutions and waters should have a temperature of 190 degrees Fahrenheit, at least. All sheets not uniformly cleaned by this treatment should be rejected. Before painting, the plates should be numbered by making cuts $\frac{1}{4}''$ deep in the edge with a hack-saw.

A suitable frame should be provided, in which the sheet of steel should be placed during handling in the laboratory and shipment to place of exposure. A plain picture frame, laid face down so that the plate can be placed in it, its upper side to be the side to be painted, would be suitable. A table, somewhat larger than the plate to be painted, should be provided and arranged so as to be accessible (for inspection of plate, etc.) on the four sides. A board

of a size such that it will slip readily through the frame should be fastened to the top of the table so that when the frame containing the plate to be painted is laid over this board the plate will be raised out of the frame in a horizontal position suitable for painting. Rubber suction buttons, chewing gum, wax or some such similar device or material can be placed near the corners of the supporting board to keep the plate in position during painting.

Use, in making these tests, a 2″x$\frac{5}{8}$″ flat chisel-edge flowing varnish brush made of the best quality of boiled and prepared French bristles, the length of bristles outside of ferrule to be between 2$\frac{1}{4}$″ and 2$\frac{1}{2}$″. There should be one new brush for each paint tested. After use, each brush should be cleaned out thoroughly, first by turpentine and then benzine (all volatile) and allowed to become thoroughly dry before being used for further coats. If desired, each brush may be placed in its respective paint for one hour before using.

A room should be provided, in which to prepare these tests, free from dust and corroding gases or vapors, and maintained at a temperature that will not exceed 85 degrees Fahrenheit or fall lower than 65 degrees, with a free circulation of air.

Before the paints are applied, it shall be agreed either as a result of preliminary tests or in accordance with recommendations from manufacturers as to the spreading rate per gallon, according to which each paint shall be applied, also the number of coats and the time to be allowed for between coats. Ordinarily, a paint shall be considered dry and ready for further painting two days after it shall have become sufficiently dry to resist thumb pressure.

The specific gravity of each paint as it is ready to apply shall be determined by weighing 100 c.c in a graduated flask at 70 degrees Fahrenheit, multiplying this specific gravity by 8.33 to get the weight of the paint in pounds per gallon, or by 3785.4 to get its weight in grams.

A beam balance, accurate to 10 milligrams, is desirable for the proper conducting of these standard tests.

To conduct a test, place the sheet of steel to be painted horizontally on the described support, clean it very thoroughly; take a sufficient amount of paint thoroughly mixed and place it in a distemper glass; weigh the glass, paint and brush to be used; find the amount of paint to be applied per coat by the following formula:

A—Spreading rate per gallon adopted.
B—Weight in grams per gallon of paint.
C—Surface to be painted—equal to 6 square feet.

$\frac{C \times B}{A}$ = Amount of paint in grams to be used for each coat.

Apply the paint to the surface, brushing it back and forth until the amount required shall have been applied in a smooth and even coat. Then place the sheet of steel horizontally on a suitable rack with the painted surface upwards and allow it to dry for the length of time agreed upon to start with. Two days before each plate is to receive a second or third coat, it shall be placed in a vertical position with free access of air and in bright diffused light. When a second coat shall be applied—if such second coat is called for—it shall be done in the same manner as the first coat; and a third coat, after the second coat has dried—if such third coat is called for—etc., etc.

Preliminary to the making of this test, the thickness of the sheet of steel shall be determined at accurately located points by a delicate micrometer callipers; and when the painting test is completed, the thickness shall again be determined at these points, thereby obtaining the thickness of the paint film.

Before exposing the paint, two striping coats shall be applied around and over the edge, front and back, to a width of one inch. No other paint should be placed on the back of the steel plate, to which should be allowed free access of air.

Test plates should be prepared in triplicate for each paint, with the end in view that after exposure the plate which appears to show the average conditions of the three shall be used for comparison with similarly selected plates painted with other paints.

GUSTAVE W. THOMPSON,
Chairman.

REPORT OF SUB-COMMITTEE ON THE PERMEABILITY OF PAINT FILMS.

The Sub-committee on Permeability of Paint Films, has only a meagre report to make, owing to extreme pressure of work, which has prevented any elaborate experimentation. Some tentative attempts have been made to determine whether paint films

actually were porous or spongy, by studying films under the microscope. Thus far no satisfactory conclusions have been obtained from this study. With the best microscope at the service of the Sub-committee, it was not possible to detect any definite appearance of porosity. The examinations were made by painting a film on glass and then examining the film by both transmitted and reflected light. By neither examination could any spongy appearance be detected in the film. Possibly a better method of experimentation might develop something.

The Sub-committee members are under very great obligations to the studies of Mr. G. W. Thompson, who is a member of the General Committee, for a proposed method of obtaining paint films. (See description of method in the Report of Sub-Committee on Permanency of Paint Films.)

The films that the sub-committee has seen made in this way, seem to offer an admirable chance for studying permeability. The sub-committee has in mind using these as a diaphragm, with the idea of seeing whether the permeability of the film is a question of osmosis, and also further studies.

It is to be regretted that the amount of time at the disposal of the Sub-committee has been so limited, and that the progress has been so small.

C. B. DUDLEY,
Chairman.

REPORT OF SUB-COMMITTEE ON PERMANENCY OF PAINT FILMS.

The Sub-Committee appointed to investigate the subject "The Permanency of Protective Coatings," beg to report as follows:

The time which has elapsed since the appointment of this committee has not been sufficient to enable it to carry on any original investigation along the lines developed in its discussion; therefore, at the present time, it is only in a position to point out what it believes to be the common destructive influences which affect the permanency of such coatings and to suggest a plan which seems capable of giving at least rough indications of the relative ability of various coatings to resist any given destructive condition.

Permanency in protective coatings must always be considered relatively as none are absolutely permanent under all conditions. It is recognized that some withstand certain conditions better than others, and a plan which will indicate these differences must be of value. Protective coatings vary in permanency as a result of chemical change, solvent action, physical change as a result of heat and changes of temperature, and abrasion. The chemical change common to all oil paints, and which we call drying, may be said to be the most common destructive agency. This process cannot be stopped when the coating has become firm and tough, but proceeds until it has become brittle and inelastic. The character of the japans added to induce drying seem to have much to do with durability, those which have been made at relatively low temperatures being less destructive than those made at higher temperatures.

The permanency of the film is undoubtedly largely affected by the chemical relations of the pigment to the binding material. For example, if linseed oil and japan are the binding materials, and the pigment is of such a nature that there is chemical action between the pigment and the oil, or the constituents of the japan, the life of the film will usually be short.

Rain water always contains a little ammonia which is a solvent of dried linseed oil, so that there would result a slow solution and washing off of the binding material of the paint. The action must be more rapid in those localities where large quantities of soft coal are burned.

All chemical changes are accelerated by heat, so that heat is ordinarily considered as one of the most destructive forces which protective coatings have to withstand. Paint on the south side of structures fail more rapidly than on the north, simply because of the higher average temperature. The effect of light, independent of heat, on the duribility of coatings is obscure.

The departure of a paint film from its best condition toward ultimate failure is usually marked by a decrease of elasticity and an increase of brittleness. When the coating is on a support it is difficult to detect relative differences in these respects. The method of preparing paint films for purposes of investigation, has been to coat plates of zinc and to remove the zinc by dilute sulphuric acid solution. There are two objections to this method, one is

that zinc itself has certain drying properties, and second, that dilute sulphuric acid produces slight changes on certain metallic oxides and pigments.

A method has been suggested by Mr. Thompson which does not appear to have any objectionable features. Take a piece of tinned plate, amalgamate this thoroughly with mercury—dry—rub off the excess of mercury and repeat this operation after the end of twelve hours. If this amalgamated surface is painted with linseed oil paint, the paint may be removed from the surface almost intact, when dry, by rolling it on a glass rod $\frac{1}{2}$ inch in diameter, from which it may be unrolled and hung in a proper place until needed for testing. Films so prepared may be subjected to such accelerating and destructive influences as may be desired and their relative behavior noted. Changes in elasticity, weight, specific gravity, shrinkage, tenacity are to be looked for, and when found are to be considered signs of decay.

An investigation along these lines is not of course expected to give exact information, but if in such a test one coating resists any given condition better than others subject to the same conditions, it is a fair assumption that it will do the same in practice.

Whenever a test for resistance to abrasion is needed it is best made by allowing a fine stream of sharp sand to fall from a fixed height upon the coated plate at certain fixed angles. The test should not be made on freshly painted plates but upon such as have been subjected to a moderate degree of heat, so as to bring this coating to a condition it would arrive at in practice after being exposed for a length of time. This, in general, is the suggestion of a means of gaining hurried information as to the relative permanency of protective coatings. It can best be applied to linseed oil coatings, which change most because of chemical alterations, and is not so well applicable to varnish-like coatings, where the changes are due less to chemical than to physical forces.

MALCOLM McNAUGHTON,
Chairman.

REPORT OF SUB-COMMITTEE ON PREPARATION OF IRON AND STEEL SURFACES FOR PAINTING.

In order to secure the best possible result from a preservative coating it is quite necessary to have the surface of the steel free from dirt, rust, detachable mill-scale and grease.

In order to secure this result we would recommend the use of hammers, steel scrapers, and wire brushes. Oil and grease should be removed by the use of benzine.

The process of cleaning steel most talked about and least practiced is the sand blast. The two principal reasons for this are, first, the menace to the output of the shops; second, the cost of the process, in consequence of which it has not been sufficiently practiced to reduce it to a practical process, and the members of this Committee are not in possession of sufficient knowledge regarding the same to make any recommendations.

Some of our members have in the past made considerable inquiries upon the subject, and always met the proposition that it is impracticable owing to the lack of space in the shops for properly doing the work.

If we were in possession of any data to justify such a course we would recommend that specifications for cleaning steel in this manner be insisted upon, and in case these recommendations were insisted upon by the parties in interest, the various shops would, no doubt, provide themselves with ample room to comply with such specifications.

The shop coat of paint should be applied under cover with a temperature not below 50 degrees, Fahrenheit. Better results can be obtained at a higher temperature. We further recommend that the shops should not only be warm, but dry and properly ventilated, as the durability of protective coatings is increased when the process of drying is carried on in atmosphere free from moisture. Increased rapidity of drying is secured at the expense of the durability of the paint.

During erection we recommend an inspection coat. By this we mean all abrasions that have occurred during transportation and erection shall be painted with the same paint and the same color as the shop coat, and then the steel shall be given two field coats, each coat of different color, than the preceding coat, in

order to facilitate inspection and secure proper application of each coat, and to get the desired results, allowing, of course, sufficient time for drying between coats. The paint may be considered dry when a sliding pressure of the thumb shall fail to remove it.

J. W. WHITEHEAD, Jr.,
Chairman of Sub-Committee.

DISCUSSION.

Mr. G. W. Thompson.—As to whether paint is permeable or not, little definite knowledge is attainable. Once in a while, we get a suggestion which throws some light on the subject; for instance, Dr. Toch has shown us what he calls "progressive oxidation with blistering." Where blistering takes place, it seems to me that the film is impermeable; because, if it is not impermeable, the gases generated would go through and no blisters would be formed. So in house painting, on wood, or wherever blistering occurs, it is safe to assume that moisture is underneath and that gases are generated which cannot get through the paint. Painters have been known to say: "We do not use boiled oil for the finishing coat, because it blisters." If they are right, then boiled oil tends to produce a more impermeable coating than raw oil. These are simply suggestions. Mr. Thompson.

Some time ago, it occurred to me to try to make paint films, thinking that it would be useful in the determination of their permeability under various conditions. I have here paint films made with Prince's Metallic Paint and linseed oil; white lead and linseed oil—this is quite elastic; linseed oil film alone, with just a little varnish added to it; Prussian blue film, which is almost like blue glass in transparency; a varnish film—very inelastic; and a red lead film, which is quite heavy.

As to the question of the permeability of paint films, it occurs to me that some notions which have grown in the last couple of decades are not altogether sound. In the olden time, it was only genuine boiled oil that was used, and there are some manufacturers to-day who make their preservative coatings—practically varnishes—from boiled oil, and yet, without any reflection on these manufacturers, they are ready to blame linseed oil as a protective paint constituent, although they use linseed oil, properly prepared, in their own coatings. If these manufacturers are as wise as this, why should not the consumer be equally wise and use a genuine boiled oil in preparing his own paints. It seems to me

Mr. Thompson. that we may have gone too far in the direction of believing that we can take raw linseed oil and dryer and get durability equal to that obtained when an oil is used that has been heated to 500 or 600° Fahr. From recent observations, I feel that I have reason for the belief that a genuine boiled oil is more durable, more resistant to atmospheric influences and has less of a tendency to become hard and brittle—that is to say, it has more permanency.

Mr. Toch. MR. MAXIMILIAN TOCH.—In regard to what Mr. Thompson said about the thickening of linseed oil and using it for exposure, I have looked into that and the ideal oil made of that character is the oil used in making patent leather. That oil is heated to from 550 to 560° Fahr., and the dryer added. I made a series of tests which cost me a large amount of money because I went to patrons and asked them to allow me to paint with paint made of this thickened oil to see how much surface the paint would cover, and how well it would stand against north-east exposure in New York. I have the photographs and hope to give you a talk on that subject some other time. The oil would absorb as much as 18 per cent. of oxygen in drying and the volume would increase so much that it would get away entirely from its base. It would not blister but come off in sheets. You know patent leather is only subject to an exposure of a few hours out of the twenty-four, or, perhaps twelve hours, at most, half the time being in the shoe closet at a normal temperature. Unless patent leather is kept under normal conditions it will not last.

I should like to say a word on the question of rapid drying, or dryers. I quite agree with President Dudley that paint that will dry in two hours might be as good as paint that takes a week to dry; but I fear we have overlooked the main issue of the question in not specifying what the word means. The ideal dryer is one which stops oxidization when the film is dry. If you produce that you have a paint which has the longest life. There is, however, another side to that story, and that is, eliminating the question of dryer altogether, why shouldn't a paint be made which would dry by evaporation and answer all the purposes for which it is intended? Why should a piece of board be painted with paint that contains a dryer? Why cannot a film be invented which excludes all these things?

The President. THE PRESIDENT.—It is frequently held that the rate of drying

of a paint, is an element in its value, and that slow drying paints are better than rapid drying ones. Our studies have rather led us to think that this statement is more or less fallacious. The drying of paint is a chemical operation, and while time is an element in all chemical operations, long continued time is apparently not essential in the drying of paints, and we believe a paint might dry in two hours, and still be as durable as if it required a week for drying. Our thought and experience have been, that the trouble with rapid drying paints has been poor japans. An experiment which we made some years ago might throw a little light on this subject. Three painted boards were prepared for exposure, two different japans being used to produce drying. Each japan had about half its weight volatile matter, turpentine. The same pigment ground in raw linseed oil was used in all cases, and the paints were diluted for spreading, so that in each case there was 50 per cent. by weight of pigment, and 50 per cent. by weight of liquid. The difference in the paints was in the amount and kind of japan present. Board No. 1 was painted with two coats, containing only 5 per cent. of an oil japan. These coats required 12 to 24 hours for drying. Board No. 3 was painted with two coats, containing $33\frac{1}{3}$ per cent. of shellac japan. The other constituents besides the japan in every case were raw linseed oil and pigment. This board No. 3 was second-coated in two hours. Board No. 2 had a coat similar to No. 3 for first coat, and a coat such as was used on No. 1 for second coat. These boards were exposed on roofs and vertically, where they were subjected to smoke from locomotives and the weather for three years, and were then examined by the master painter, who knew nothing of how they were painted. His verdict was that all three were in a magnificent state of preservation, and could have remained three to five years longer. No. 1 was slightly more elastic, as would be expected; No. 2 next, and No. 3 least elastic, but there was no appreciable deterioration in any of them. We are clearly of the opinion that the rate of drying is not the important element that has been believed. **The President.**

MR. ROBERT JOB.—Our results have indicated that the quality of the japan makes the greatest possible difference in the durability of the paint film. **Mr. Job.**

On the one hand, a comparatively large proportion of a well-

Mr. Job. made, moderately cooked japan has given good service, while on the other hand a much smaller proportion of a hard-cooked japan has caused rapid deterioration. Possibly the difference lies in the difference in the solubility under the two conditions. In the first, the material diffuses uniformly throughout the oil, while the japan when hard-cooked, tends to separate into clots or flakes and thus does not give a uniform mixture with the oil.

Several years ago we took up the problem of drawing up specifications for japan and the results have been exceedingly satisfactory. After a study of the matter we reached the conclusion that it is desirable merely to specify tests which would ensure the qualities which from practice we had found desirable, and to leave the composition almost wholly to the manufacturer. By this means we have found it practicable to get the requisite strength and to ensure suitable cooking of the material, and presence of other properties found necessary to the best service under our conditions, by means of very simple tests which any manufacturer can readily make.

In working out standard specifications for protective coatings for iron and steel our thought has been to follow this same general plan, that is, not to specify an exact composition, but merely certain definitely arranged tests which if complied with, by any material, will render certain good service.

Mr. Harrison. MR. A. B. HARRISON.—There is one point which has not been brought out in this very interesting discussion, and that is the adhesive qualities of paints, which I think is important. In order that a paint preserve the metal to which it is applied, it is essential that:

First.—It should adhere closely to the surface coated, under all conditions to which the surface is subjected.

Second.—It should be non-porous and unaffected by the action of all acids, alkalies, fumes, gases, water, weather, heat, cold, etc.

To secure a coating having these properties has been my study during the last two years. I having given my undivided time and attention to this subject, having made hundreds of tests and experiments under varying conditions, and the results attained are encouraging.

I learned from authorities that the magnificent sculptured slabs of alabaster that adorned the palaces of Babylon and Nine-

veh, although set thousands of years ago, are still in place. Upon investigation it was found that the material of which this cement is composed, resists decay in almost all its forms. Taking this material for the base or pigment for the coating, by a simple means of refining, using a solvent to reduce the material to liquid form, we secured a coating that I believe to be the nearest approach to a rust-proof coating ever applied to metal. The solvent evaporates quickly after application, leaving the surface coated with a mineral wax composed of hydro-carbon, having a percentage of ozokorite combined by nature, just as nature made it, without addition or adulteration. **Mr. Harrison.**

Besides resisting the action of all acids, alkalies, water, fumes and gases to a degree that is simply wonderful, its adhesive qualities are phenomenal, and it remains elastic. Pieces of glass or glazed tile, coated, and laid one on the other, seem actually to grow together in a few hours, and cannot be separated.

The remarks of one of our members relative to the abuses to which the coating on steel cars are subjected, bring to mind the report of the master painter of one of our large coal-carrying roads, who, after testing this coating, said: "The use of a sledge on the side of the car failed to do more than spread the coating, and did not expose the metal, and even the coal could not scrape it off the inside of the car."

I solicit co-operation on the part of my fellow members in the investigation of the properties of this coating, and I shall be glad to have the manufacturer send samples to any member who may desire to satisfy himself as to its efficiency.

J. W. WHITEHEAD, JR. (by letter).—Some years ago I went into the subject of preparing steel surfaces for painting to a considerable extent, and discussed it with engineers of various steel plants and assembling shops. My idea at first was favorable to sand-blasting, but on investigation I found opposition on the part of all manufacturers and assemblers of steel on the ground that the object could not be attained by this method within any reasonable limits of time and expense. The engineers of the various companies with whom I discussed this subject invariably took the position that, owing to the length of time necessary by this mode of cleaning it would block their mills and shops and thereby reduce their output. Some of them went so far as to say that where specifications **Mr. Whitehead.**

Mr. Whitehead. called for sand-blasting in the shop or the mill, they would refuse to take the order. They all admitted, however, that it was necessary to develop some plan of getting rid of the mill-scale, as it contains a large percentage of oxygen, and is without doubt a factor of danger which would in time cause the deterioration of the steel on which it was allowed to remain.

Mr. P. T. Berg, Mechanical Engineer of the Homestead Steel Works, Carnegie Steel Company, was especially interested in my inquiry, and I discussed with him, personally and by correspondence, the various plans of cleaning steel surfaces.

In a letter dated September 1st, 1900, he gave me the percentage of the ingredients of his Bessemer and open-hearth steel and said, "that they are combined chemically with the steel and cannot affect the paint" . . . . . . "The scale formed on the surface contains about 72 per cent. of iron, the balance being oxygen."

From this analysis of the scale it is plainly evident that the steel before leaving the rolls has already begun to return to its original and natural condition in which it is taken from the mines. The ore is found in an oxidized form, and by chemical and mechanical processes the oxygen is eliminated and the particles of iron are united and turned into steel, a condition entirely unnatural and subject to deteriorations from all atmospheric conditions. The question now is to clean the surface so as to eliminate all traces of oxygen before applying a preservative coating in its present and new condition of life.

Plate-steel from which large members for bridges and other structures are made offers the least trouble in cleaning owing to the manner in which it is treated during rolling. The scale found on its surface is but a very thin film created by its last passage through the rolls before going upon the cooling beds. After being exposed to the atmospheric conditions for a short time, it soon curls up and is easily brushed off. In the case of I-beams and other shapes, the question is quite different, for with every pass through the rolls the scale is thickened and hardened, and it is impossible to detach it in the ordinary way of shop cleaning.

Noticing the quick action of the elements on the thin mill scale of steel plates, I acted upon the theory that an extended exposure of I-beams and other shapes, to the elements, would cause the scale formed on the surface to act in the same manner as

that upon the steel plate, if sufficient time were allowed, and I accordingly made some experiments with a number of new I-beams. Mr. Whitehead.

I placed them in the open on wooden horses, and on beam No. 1 I allowed the elements to act in their natural way; on beam No. 2 I sprinkled clear water every morning from a hand-sprinkler; on beam No. 3 I sprinkled diluted acetic acid in like manner, the action of which in the open air would correspond to what we might term "di-oxide," and on beam No. 4 I sprinkled salt water.

I kept this up for sixty days, at the end of which time, the one sprinkled with salt water was very badly rusted; the mill-scale had entirely disappeared and the steel itself had been attacked. Beam No. 3 was in a similar condition, but to a less extent, while on beam No. 2 the mill-scale was in very good condition for cleaning; it had raised from the surface of the steel and was easily detached. Beam No. 1, that had been exposed to the elements only, was in very good condition. It took an additional thirty days before the mill-scale on this beam was in condition to be properly removed, and so far as it was possible to ascertain by a physical examination, no particular bad effects upon the steel had developed.

In addition to these experiments I visited various assembling shops and examined closely the steel which they had in stock after obtaining the dates on which they had received the various lots of steel, I found in every instance that the surface of the steel which they had in stock anywhere from three to four months was in excellent condition for cleaning, that is the shop-scale had been sufficiently affected to be easily removed without affecting the main body of the steel. Where the scale had been removed by handling there were signs of incipient red rust which was easily removed with a wire brush and broom.

Mr. E. C. Schankland, of the firm of E. C. & R. M. Schankland, of Chicago, who was Chief Engineer of the Chicago Columbian Exposition, was interested in this subject and made some investigations at about the time to which I allude, and came to the conclusion that the only way to get rid of the shop-scale was to "rust it loose," and having the courage of his convictions he wrote his specifications accordingly. These specifications have given excellent results, as the following copy of a letter to me from Mr. E. C. Schankland, under date of June 7, 1905, will certify:

Mr. Whitehead. "The enclosed is the specification for painting for the Dubuque and Wisconsin Bridge over the Mississippi River at Dubuque, Iowa. The bridge was erected in 1901-2.

The specification was carried out; although the shop, where it was fabricated, kicked vigorously and wrote several times asking permission to put on a shop-coat, saying they did not like work to leave their shop in such an unworkmanlike condition.

The result was entirely satisfactory, although the metal stayed around for several weeks and was covered with red rust in some cases, yet the mill-scale was almost gone and what was left was easily removed. It was cleaned with wire brushes, and although the regular bridge painters left before much painting was done and green men had to be used, it was a most excellent job of painting and is now in first-class condition. I ascribe the good result mainly to removal of the scale during transportation, shop work, etc., and this because there was no coat of oil or paint to keep the scale on the metal.

We have used this specification on every job since, but in many cases it has not been carried out, because the owner or architect is fearful that the red rust deteriorates the metal, or they object to its appearance, and in almost every case the shops object, though I imagine the real objection is not that given above.

Among the buildings where steel work was not painted until after erection were the La Salle Station occupied by the L. S. & M. S. and C. R. I. and P. R. R.; Kent Building; Thomas Church Building.; and, if my memory is right, the Chicago Edison, Market Street Sub-Station.

We are firmly convinced that neither oiling nor painting accessible surfaces until after erection gives very much the best results.

The specifications referred to in Mr. Schankland's letter are as follows:

All material before leaving the mill or shop, to be thoroughly cleaned from all scale or rust.

In riveted work all surfaces coming in contact to be painted before being riveted together. All surfaces not accessible for painting after erection, to receive two coats.

After erection, surfaces to be cleaned wherever necessary, and thoroughly and evenly painted two coats of pure red lead mixed with pure linseed oil, 33 pounds of lead to be used to each gallon of oil in the first coat and 25 pounds of lead for each gallon of oil for the second coat. In the second coat, one pound of the best lamp-black to be added for each six gallons of oil used.

Pins, pin holes, screw threads, and other finished surfaces to be coated with white lead and tallow before being shipped from the shop.

From my own experience and observation, I am satisfied that this is the true solution of the question under discussion. The

exceptions to this rule will be only where steel is to be assembled and stored for a number of months before erection. Mr. Whitehead.

With the adoption of this system the only parts painted in the shops would be the surfaces coming in contact in riveted work, bottom of bed plates, bearing plates, and any parts that are not accessible for painting after erection. After the steel has been erected a corps of cleaners provided with hammers, steel scrapers and iron brushes, should precede the painters and properly clean all surfaces.

The question of sand-blasting has been thoroughly discussed at various times by parties in interest, and has been practiced to some extent; but, so far as I have been able to learn, it has never been reduced to a scientific or practical basis to the extent that it ceases to be a menace and hindrance to the manufacturers of steel. In fact the information obtained through the interviews which I have had, not only with the superintendents of steel mills and assembling shops, but also with the superintendents of railroad companies and railroad construction companies, who have done sand-blasting in the field, shows that so far as their experience is concerned this method is impracticable and does not really secure the desired results within reasonable cost. It is a question of wearing away the mill-scale by the force of the sand-blast rather than its removal by disruption. The time required is altogether too long, and hence this process is too expensive.

Sand-blasting brings up the question of shop output. The majority of the assembling shops are altogether too small for the output desired by their owners and in consequence of this fact the cleaning of the steel, before applying the shop-coat of paint, is sadly neglected. Exceptions to this rule are rare, and where the right methods are adhered to the results are apparent to even a casual observer. Such shops are well-known and esteemed by all of the manufacturers of paints of the higher grades.

By the neglect of proper cleaning, the assemblers become the steel's worst enemy. The structural engineer figures the minimum amount of steel to carry the maximum load, using a reasonable factor of safety to overcome any defects of manufacturing. He assumes that all deteriorating elements such as mill-scale, dirt, and rust will be removed before the preservative coating is applied which is intended to maintain the steel in good condition indefi-

Mr. Whitehead. nitely. If the shop neglects its work by omitting the most essential part, namely: the proper cleaning of the surface of the steel before applying the preservative coating, then that shop becomes a factor of danger of which the engineer has taken no account in his calculations. I believe that I voice the sentiments of all engineers and investors when I caution the assemblers to stop in their rush to dispose of tonnage and to prepare the surface of their product properly before painting, or else this neglect may bring about the use of some other material of construction. This subject is, in fact, under discussion in all quarters, owing largely to the rapid deterioration to which steel is subject, caused primarily by its treatment before passing from the hands of the assembler.

REPORT OF COMMITTEE G ON THE MAGNETIC TESTING OF IRON AND STEEL.

Your Committee is able to report progress along the several lines of investigation proposed in the report of one year ago. In view of the desire to carry these investigations further than they have now progressed, the Committee has thought it desirable to withhold a statement of the results obtained until the specific experiments now in progress shall have been completed.

The Committee would make acknowledgment of the assistance which has been rendered by the various manufacturers of electrical iron and steel, as well as the manufacturers of electrical machinery, who have assisted the Committee by supplying samples for testing and offering valuable suggestions.

Respectfully submitted on behalf of the Committee,

WALTER G. ESTERLINE,

Chairman.

REPORT OF COMMITTEE H ON STANDARD TESTS FOR ROAD MATERIALS.

The Committee on Standard Tests for Road Materials respectfully reports the following:

The third meeting of the Committee was held in New York, on January 17, 1905. The work of the several sub-committees, was discussed and arrangements made for continuing the different lines of investigation.

The fourth meeting of the Committee was held at Atlantic City, June 29, 1905, and the following specifications from the sub-committees on macadam tests and asphalt tests were approved by the Committee and are respectfully recommended to the Society for adoption.

Specifications of Toughness Test for Macadam Rock.

In the consideration of macadam road materials, toughness is understood to mean the power possessed by a material to resist fracture by impact.

In testing macadam rocks under impact, it has been found best to apply a number of blows of successively increasing energy and note the blow causing failure. The following test involving this principle is, therefore, recommended for determining the toughness of rock for macadam road building.

1. Test pieces may be either cylinders or cubes, 25 mm. in diameter, and 25 mm. in height, perpendicular to the cleavage of the rock. Cylinders are recommended as they are cheaper and more easily made.

2. The testing machine shall consist of an anvil of 50 kgs. weight, and placed on a concrete foundation. The hammer shall be of 2 kgs. weight, and dropped upon an intervening plunger of 1 kg. weight, which rests on the test piece. The lower or bearing surface of this plunger shall be of spherical shape having a radius of 1 cm. This plunger should be made of hardened steel, and pressed firmly upon the test piece by suitable springs. The test

piece should be adjusted, so that the center of its upper surface is tangent to the spherical end of the plunger.

3. The test should consist of a 1 cm. fall of the hammer for the first blow, and an increased fall of 1 cm. for each succeeding blow until failure of the test piece occurs. The number of blows necessary to destroy the test piece is used to represent the toughness.

STANDARD METHOD OF ANALYSIS OF BITUMINOUS PAVING MATERIALS.

The method consists in treating a definite quantity of the material under examination with a specified amount of carbon bisulphide at ordinary temperatures, allowing this to stand undisturbed for a sufficient time to permit of a subsidation of the insoluble matter. The solution is then decanted off into another receptacle and the residue again treated with the solvent.

After standing a second time for subsidation, the two solutions are filtered through a Gooch crucible, fitted with an asbestos plug. The filtrate is then evaporated down and the residual bitumen burnt off and the weight of the ash added to that of the residues in the receptacle and on the filter. The difference between the weight of the substance taken and the combined weight of the residues, is the bitumen extracted.

It is further recommended that this method be applied to the extraction of bituminous paving materials with naphtha.

While this method for the examination of bituminous materials has been agreed upon, there yet remains to be described minor details relating to the character and quantity of materials used in making the tests; and it is, therefore, recommended that the specifications for these tests be referred back to the Committee with power to act.

Respectfully submitted on behalf of the Committee,

LOGAN WALLER PAGE,
Chairman.

A. N. JOHNSON,
Secretary.

DISCUSSION.

The President. THE PRESIDENT.—Apropos of this question of bitumen or asphalt for paving, an interesting hypothesis has recently been brought forward by those who are working on water-proofing materials. The hypothesis is not offered as a demonstration, but as something which may possibly be confirmed by subsequent study. It is, if coal tar of proper consistency can be kept away from the sun and air, it will last almost indefinitely; on the other hand, if asphalt can be kept away from water, it will last equally long. We are all familiar with the failure of asphalt in streets, and every one who has observed knows that the first failure is in the gutter, or in some spot which is a bit low, and thus holds water. Furthermore, some water pipes whose history was known, have recently been dug up in New York, after having been down forty years, on which the coal tar coating was found to be in a perfect state of preservation.

Mr. Taylor. MR. W. P. TAYLOR.—In the Committee's work on the standardization of asphalt tests, it seems to me one of the most important details to be considered is the determination of a definite or standard method of making penetration tests. It should be stated what penetration of asphalt means, what is normal asphalt or bitumen, and what the penetration of the different asphalts should be to get the best results; in addition to the standard method for determining it. In specifications at the present time, it is customary to stipulate certain limits of penetration without defining the manner of conducting the test, thus making the requirement almost valueless.

At present there are two needles which give widely varying results, and an asphalt passing the requirements with one needle will fail with the other. Since this test is being introduced into almost every specification for asphalt, the Committee should take speedy action in standardizing it.

Mr. Page. MR. L. W. PAGE.—The Committee considered these tests very carefully along the lines Mr. Taylor refers to, and a great many other tests relating to asphalt. We shall take up these matters as soon as we possibly can.

REPORT OF COMMITTEE I ON REINFORCED CONCRETE.

Committee I on Reinforced Concrete has associated itself jointly with committees of three other societies, namely, the American Society of Civil Engineers, the American Railway Engineering and Maintenance of Way Association, and the Association of American Portland Cement Manufacturers, in the matter of reinforced concrete. These several societies have appointed a joint committee which has been organized by the election of a Chairman and Secretary, and the appointment of sub-committees on Plan and Scope, Ways and Means, and Tests.

The personnel of the Joint Committee is as follows:

C. C. Schneider, *Chairman.*
J. W. Schaub, *Secretary.*

Representatives of the American Society of Civil Engineers:

J. E. Greiner,
W. K. Hatt,
Olaf Hoff,
R. W. Lesley,
J. W. Schaub,
C. C. Schneider,
Emil Swensson,
A. N. Talbot,
J. R. Worcester,

Representatives of the American Society for Testing Meterials:

W. B. Fuller,
E. Lee Heidenreich,
Richard L. Humphrey,
A. L. Johnson,
Gaetano Lanza,
Robert W. Lesley,
Edgar Marburg,
C. M. Mills,
L. S. Moisseff,
H. H. Quimby,
W. P. Taylor,
S. E. Thompson,
F. E. Turneaure,
S. T. Wagner,
Geo. S. Webster.

Representatives of the American Railway Engineering and Maintenance of Way Association:

Frank Beckwith,
C. W. Boynton,
A. O. Cunningham,
W. B. Hanlon,
G. H. Scribner,
Geo. F. Swain.

REPRESENTATIVES OF THE ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS:

E. R. Ackermann,
T. J. Brady,
Norman D. Fraser,
R. A. Griffiths,
Edward M. Hagar,
S. B. Newberry.

The Voting Members of the Joint Committee are as follows:

ON THE PART OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS:

J. E. Greiner,
W. K. Hatt,
Olaf Hoff,
R. W. Lesley,
J. W. Schaub,
C. C. Schneider,
Emil Swensson,
A. N. Talbot,
J. R. Worcester.

ON THE PART OF THE AEERICAN SOCIETY FOR TESTING MATERIALS:

Richard L. Humphrey,
Edgar Marburg,
F. E. Turneaure,
Geo. S. Webster.

ON THE PART OF THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION:

C. W. Boynton,
A. O. Cunningham,
Geo. F. Swain.

ON THE PART OF THE ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS:

Edward M. Hagar,
S. B. Newberry.

The sub-committees are constituted as follows;

ON PLAN AND SCOPE:

J. W Schaub, *Chairman.*

C. W. Boynton,
Edgar M. Hagar,
W. K. Hatt,
A. N. Talbot,
F. E. Turneaure.

ON WAYS AND MEANS:

Robert W. Lesley, *Chairman.*

A. O. Cunningham,
J. E. Greiner,
Edward M. Hagar,
Olaf Hoff.

ON TESTS:

W. K. Hatt,
Olaf Hoff,
Richard L. Humphrey,
S. B. Newberry,
Geo. F. Swain,
A. N. Talbot.

The Committee on Plan and Scope has presented a preliminary report, a copy of which is appended hereto as Appendix I. The Committee has proposed certain lines of investigation and has made arrangements whereby these are to be carried out in the several laboratories throughout the country. Nine universities and colleges have undertaken to cooperate in this work.

During the past year considerable progress has been made in actual experimental work, but there has not been sufficient time to prepare a summary of the results. A brief statement of the work now in progress will, however, be prepared for publication as an appendix to this report. During the coming year, work as outlined by the sub-Committee on Plan and Scope (See Appendix II) will be continued, and arrangements have been made whereby the United States Geological Survey will cooperate in this work. In addition to the investigations now under way, it is proposed to compile results of previous tests for the use of the joint Committee.

Your Committee has decided to give its entire support to the work of the joint Committee, and for the present will initiate no work of its own, believing that the best results will be accomplished through the united efforts of the various societies.

Submitted on behalf of the Committee:

F. E. TURNEAURE, *Chairman*,
R. W. LESLEY, *Vice Chairman*,
RICHARD L. HUMPHREY, *Secretary*.

APPENDIX I.

REPORT OF SUB-COMMITTEE ON PLAN AND SCOPE OF THE JOINT COMMITTEE ON REINFORCED CONCRETE.

The sub-committee presents the following report for your consideration:

Reinforced concrete is comparatively new but it has already become of great importance in engineering and architectural construction. The development of the Portland cement industry and the improvement of the product and the rapid extension of the use of concrete are among the noteworthy features of engineering progress in recent years. It is not too much to say that with the increased demand for permanence and better appearance in structures a very great extension of the use of reinforced concrete may be expected in the next few years. However, to ensure this development and to promote safe construction, a full knowledge of the properties and principles appertaining to reinforced concrete is needed. It is no reflection to say that our knowledge of reinforced concrete is imperfect. The very newness of this construction explains the paucity of information and diversity of opinions concerning it. But the lack of information and of experience in this work and the carelessness or temerity of inexperienced or incompetent persons make the danger from accident and failure of structures very great. The importance of securing definite and complete knowledge of the principles underlying reinforced concrete construction before a serious accident caused by imperfect or improper construction injures the standing of reinforced concrete, is too apparent to need argument. Besides, the properties of concrete are not as regular or as well defined as those of such materials as structural steel, and the composite structure of steel and concrete may be expected to have a different action from that of the individual components. Recent investigations, too, seem not too confirm certain deductions considered by many to have been established. The need of a thorough and comprehensive investigation of the properties of reinforced concrete and of the principles underlying its design and construc-

tion is evident, and the sub-committee recommends that such an investigation be undertaken under the auspices of the joint committee and emphasizes the importance and the timeliness of such action to the engineering and constructional interests of the country.

It is true that many tests have been made on reinforced concrete, and valuable information doubtless exists. At the same time there is considerable diversity in results and in their interpretation. These conflicting opinions extend to so many features and even to such fundamental principles that it seems best to begin with elementary matters and to get at the subject from the foundation up. As the investigation proceeds the conditions accompanying tests already made may be more accurately learned and trustworthy data of such tests collected, and the collation of this information may be made a valuable part of the undertaking. However, the main purpose of the investigation should be to establish principles independently of existing opinions, or of preconceived ideas, and the principal present use of existing available data will be to direct the nature and scope of the work and to avoid unwarranted assumptions.

The scope of the investigation will include both (*a*) the determination of fundamental principles and properties, and (*b*) the choice of the main general conditions and requirements controlling the more common designs and constructions. The above distinction is not intended to imply that the conditions and requirements of design and construction are not dependent upon principles and properties, but rather that, as the investigation proceeds, the results may be utilized without waiting for the completion of the work outlined and that in the selection of the order of the work to be undertaken the choice should be such that items of probable immediate applicability will be taken up at first. This attention to the order of the tests is warranted by the desire of railroad and structural men to get facts upon which to base construction at as early a day as possible. At the same time it must be borne in mind that the bearing of facts and experiments upon important fundamental principles may not be recognized in advance and that care must be taken not to prejudge results nor to base conclusions on insufficient evidence. Besides, if this investigation is worth undertaking, the subject matter is worthy

of a comprehensive treatment and the Joint Committee cannot afford to stand sponsor for a superficial investigation.

The sub-committee recognizes that the field for investigation is very large. In the outline of work which follows no effort has been made to cover the whole field. As the work progresses modifications and extensions will need be made. The order of the outline given has no reference to the order in which the tests should be undertaken, nor is it expected that all these tests may be made the first year. Some of the experiments may give negative results, but this fact will not lessen the importance of making them. Some are included because they may help to uncover the field for further investigation.

As stated under Supervision and Administration the plan is to have the tests made in the laboratories of engineering schools, railroads, etc., which have facilities for the work and which upon consultation express willingness to cooperate. It is expected that much of the work will be done as thesis work by senior engineering students and that this will be greatly supplemented by volunteer investigators. Certain expenses will be defrayed from funds raised by the committee on Ways and Means. Tests along special lines may require that special arrangements be made, and special apparatus may have to be provided. A committee to be known as the Committee in Charge of Tests will supervise the work, an inspector and other assistance will be furnished, and the management of the investigation will be as described under Supervision and Administration.

Uniformity and definiteness should be characteristic of the investigation. In the plan outlined, the selection of standard forms and proportions for test specimens, the description of the concrete and of the materials, and the general methods of testing are given in order that results of tests made at different places, at different times, and by different persons may be comparable. Some preliminary experimental work will be necessary before the standard test pieces can be finally fixed, and in any event some variations from the standard form and size of test pieces may have to be made. The properties and constants of the concrete used in the reinforced concrete test specimens will also, for the purposes of comparison, be ascertained.

It is proposed by the plan to take up at the beginning the

more simple constructions and the more fundamental principles and basic properties. Especial attention will be given to reinforced concrete beams, though columns and slabs will be taken up and plain concrete will be investigated to determine its properties and constants so far as they have a bearing upon reinforced concrete. Among the problems, variations, and determinations for reinforced concrete beams included in the scope of the work are the following: Amount of reinforcement; form, size and position of reinforcing bars; variety and consistency of concrete; carefulness of concrete making; repetition of load; manner of application of load; form of section; resistance to shearing; efficiency of devices and arrangements to resist shear; bond and anchorage; effect of age; general investigation of manner of failure and of the critical or controlling condition upon which the design of beams should be based. It will be seen that emphasis is placed on the stress-deformation relation, as this has so important a bearing on the action of reinforced concrete beams.

The scope of the work may be modified and extended as the development of the investigation warrants. Special problems coming up may need attention. It may be well in the report of the committee to formulate general regulations for the proper execution of work in reinforced concrete construction. It should be stated that the plan contemplates tests of reinforced concrete, using that term to mean a construction composed principally of concrete and having a small amount of metal so embedded as to take the principal tensile stresses and perhaps the secondary tensile and shearing stresses developed but not to any great extent the compressive stresses, and does not include what may be termed steel-concrete, meaning thereby steel structures encased in concrete and using the concrete principally for stiffening and protection.

The outline of the plan and scope which follows is arranged as follows:

SCOPE OF INVESTIGATION.

I. *Properties of Concrete.*—A. Compression; B. Tension; C. Shear; D. Flexure; E. Columns; F. Volumetric changes G. Fire resisting properties.

II. *Properties of Reinforced Concrete under Simple Stresses.*—A. Compression; B. Tension; C. Initial Stresses; D. Bond and anchorage.

III. *Reinforced Concrete Beams.*—A. Simple flexure; B. Complex flexure; C. Restrained beams; D. Impact tests.
IV. *Reinforced Concrete Columns.*
V. *Reinforced Concrete Slabs.*

TESTING WORK.

I. *Materials and Mixing.*
II. *Test Pieces.*
III. *Testing.*

SUPERVISION AND ADMINISTRATION.

The full text of the plan and scope recommended is as follows:

SCOPE OF INVESTIGATION.

It shall be the purpose of the investigation to establish principles governing the action of the composite structure formed of steel and concrete and known as reinforced concrete and to determine its properties and constants. The determination of the properties and constants of the concretes used will be made so far as they have a bearing upon reinforced concrete.

I. PROPERTIES OF CONCRETE.

A. COMPRESSION.

Stress-deformation relation, crushing strength, and form of fracture are to be determined on all the varieties of concrete used in the tests and for the three consistencies named hereafter. 8x16-in. cylinders are to be used for this. Tests of a few 6-in. cubes for the several varieties of concrete will be made to give opportunity for the comparison of strength of the concrete with that of other concretes.

1. General stress-deformation relation.

    Tests to be applied by a standard method which will be decided upon at a later time.

2. Time and repetition stress-deformation relations.
   (a) Comparison of relation when load is continuously applied and when load is released between successive applications of the increasing load. In this make an effort to determine the condition of the internal stresses in the concrete while load is being released and reapplied.
   (b) Effect of a number of repetitions of stress. Determine this effect and as far as possible the internal conditions and stresses for four different partial loads, using new test pieces for each partial load.
   (c) Rest effect. Determine the effect of rest upon a test piece partially loaded and then released.
   (d) Time effect. Determine the stress-deformation relation when load is left on test piece during say three days' time.
3. Effect of age upon stress-deformation relation.
   Use 7, 14, 28, 60 days and 6 months and 1 year.
4. Effect of applied stress upon setting properties.
   Get stress-deformation relation when loads are applied to test pieces during time of setting. Use two loads and two ages for loading.
5. Stress-deformation relation for abnormal concretes.
   Use concretes not having voids filled and having them overfilled and concretes which have not been compacted in making to determine the general effect of porosity. Use concretes which have set in abnormally hot and dry air to determine the effect of lack of moisture.

B. TENSION.

Stress-deformation relation and breaking strength are to be determined on all the varieties of concrete used in the tests and for the three consistencies named, using the test pieces to be described.

1. Continuous loading.
2. Progressively released loading.

C. SHEAR.

The scope of the shearing tests of concrete will be outlined at a later time.

D. FLEXURE.

Determine from a series of beam tests the principal properties of the concretes used.

E. COLUMNS.

This series will be coordinated with the tests of reinforced concrete columns.

F. VOLUMETRIC CHANGES.

1. Shrinkage and expansion changes in setting and nature and amount of stresses developed.
2. Temperature changes and stresses and coefficient of expansion.

G. FIRE RESISTING PROPERTIES.

This may not properly be included with the strength of concrete, but it may be considered desirable to have an investigation of the fire resisting properties of concrete under different conditions made.

II. PROPERTIES OF REINFORCED CONCRETE UNDER SIMPLE STRESSES.

A. COMPRESSION.

Stress-deformation relation, change in cross section, and crushing strength are to be determined on all the varieties of concrete used for the three consistencies named, using the size of cylinder given for compression tests.

1. Longitudinal reinforcement.

   Use metal equal to 1 per cent. of the area of the test piece.
2. Hooped reinforcement.

   Hoops are to be 6 inches outside diame er, and are to be incased in concrete. Use two and three hoops of 3-16-in. metal, varying the total width up to one-third of the height of test specimen. Also use hoops made of round rods.

B. TENSION.

Stress deformation relation and breaking strength are to be determined on all the varieties of concrete used in the tests and for the three consistencies named, using in general the test piece to be described.

1. General stress-deformation relation.
   Use three percentages of metal with both plain and deformed bars.
2. Effect of adhesion and grip of the concrete upon the elastic properties of steel, both before and after cracks appear in the concrete. Use a special form of test piece with two different amounts of encasing concrete.
3. Effect of initial stresses in both concrete and steel. This is to be taken in connection with the tests on initial stresses.

C. INITIAL STRESSES.

Effect of volumetric changes (setting and temperature). Test piece and method to be decided upon later. Use one kind of aggregate, 2 mixtures and 3 consistencies. Determine relations for concretes (1) set in air and (2) set in water.

D. BOND AND ANCHORAGE.

The term bond will be used to include the resistance to the slipping of a bar in concrete due to (1) adhesive resistance along the surface of the bar, (2) frictional resistance resulting from the shrinkage and grip of the concrete on the bar, and (3) resistance due to irregularities or variation in shape of bar commonly known as deformed bars.

1. Plain bars.
   (a) Effect of consistency of concrete. Use three proportions of water, and two mixtures of concretes.
   (b) Effect of variety of concrete. Use the mixtures of concrete used in the reinforced concrete beams.
   (c) Effect of condition of surface: scale, rust, oil, paint, etc.
2. Effect of shape of bar.
   (a) Plain bars, round, square, flat (2).
   (b) Deformed bars. Use the various patented forms of bar.
3. Anchorage.
   (a) Bars with enlarged ends.
   (b) Bars with ends bent.
   (c) Bars connected to anchorage pins or plates.
4. Relative value of surface adhesive resistance and of grip. Make tests (a) for surface adhesive resistance, and (b) for combined friction and surface adhesion, making measure_

ments of the shrinkage and swelling with different methods of storage (i. e., immersed in water, stored in moist air, and stored in dry air).

5. Permanence of bond.
   - (a) Effect of chemical action on bond, including use of salt water.
   - (b) Effect of vibratory motion or unsteady loading.
   - (c) Effect of repetition of loading.
   - (d) Effect of impact.

III. REINFORCED CONCRETE BEAMS.

A. SIMPLE FLEXURE.

Simple flexure is here used to include flexural action which makes horizontal tensile and compressive stresses the controlling factors, as found in beams in which the dimensions and methods of loading do not necessitate special or unusual provision to resist shearing stresses and secondary or diagonal tensile and compressive stresses.

The general phenomena of the flexure will be observed as the load is applied. Observations will be made to determine the horizontal deformations, the deflection, position of neutral axis, time of appearance, nature, and growth of cracks, and general conditions for loads up to the maximum load and in part of the beams for loads up to the ultimate load and final failure; also the amount of the maximum load and conditions governing it. Any other condition or appearance having a bearing upon the establishment of laws governing maximum load, allowable load, and permanence of structure under load or when subject to loading will be noted. For the principal series all the varieties of aggregate and all the mixtures of concrete will be used.

1. Effect of amount of reinforcement. Use varying amounts of metal, ranging by say ¼ per cent. of area of cross section from perhaps ¾ per cent. to an upper limit which will develop full compressive strength of the concrete and in some cases to an even larger amount. Use all the mixtures of concrete. Use plain steel bars of low (say 30 to 35,000 lbs. per sq. in. elastic limit), medium (say 45,000 lbs. per sq. in.), and high (say 60,000 lbs. per sq. in.).

2. Effect of elastic limit of metal. This is included in the foregoing.
3. Effect of form, size, and position of reinforcing bar. Use two percentages of metal. Use best mixture of concrete and the wet consistency.
   (a) Deformed bars.
   (b) Round, square, and flat bars.
   (c) Bars in two layers.
4. Time tests, repetitions, and set.
   (a) Comparison of relation when load is continuously applied and when load is released between successive applications of the increasing load. Make an effort to determine the conditions of stress in the concrete while load is being released and applied.
   (b) Effect of a number of repetitions of load. Determine this effect, and as far as possible the internal conditions and stresses for four different partial loads, then continue the loading to failure, using new test pieces for each partial load.
   (c) Effect of rest upon a beam which has been loaded within the elastic limit of the steel and the load released. Use three partial loadings.
   (d) Effect of time upon deformation and deflection and set when load is left on beam for say three days. Use three partial loads.
5. Effect of uniform loading. Test beams with points of application of loads sufficiently numerous to approximate uniform loading and compare with the results of standard loading.
6. Tee sections, trapezoidal and other forms. The position of neutral axis, the limiting percentages of steel to develop crushing strength of concrete, and other properties will be determined for such mixtures and combinations as seem practicable after the work of the year has been further developed.
7. Composite beams. Effect of mixtures varying in richness or composition in the upper and lower layer and of the making of upper layer at a later time as when a floor slab is placed on a girder. This work is to be outlined at a later date.

8. Effect of size. Beams of different dimensions but having the same method and percentage of reinforcement will be tested to find whether results with the standard size used are applicable to beams having other dimensions.

B. COMPLEX FLEXURE.

Complex flexure is here used to cover flexural action requiring the consideration and determination of internal stresses and deformations other than the horizontal tensile and compressive stresses commonly considered in beam action. The work will include an investigation of the needs and the effectiveness of various devices and arrangements for strengthening beams against shearing action and secondary or diagonal tensile and compressive stresses.

In addition to the observations and determinations named for the tests in SIMPLE FLEXURE, such observations and measurements of deformations, cracks, and other conditions will be made as seem to have a bearing upon the determination of these shearing and secondary stresses and upon the effectiveness of provisions for resisting them. The detailed arrangements for these tests will require considerable thought and planning. One method will involve a variation in the point of application of the loads, changing from the middle toward the two ends, to vary the relative value of shear and horizontal stresses. For some of the arrangements beams of different lengths may be used. In general, the limiting amount of reinforcement will be used.

1. Effect of bending reinforcing bars into an inclined or diagonal position. Use both plain and deformed bars. Find effect of unsymmetrical loading. Use some weaker concretes as well to determine law.
2. Effect of stirrups and similar devices.
3. Effect of anchorage. This will include bent ends, enlarged ends, and ends tied to anchorage devices.
4. Effect of winged bars. This includes the so-called trussed bars.
5. Effect of deformed bars used in horizontal position. This series will be combined with the similar series of SIMPLE FLEXURE.

6. Variations of some of the series above with tee-shaped and other sections, including putting reinforcement in two layers.
7. Effect of uniform loading. Tests beams with the points of application of the load sufficiently numerous to approximate uniform loading and compare with the results of standard loading.

C. RESTRAINED BEAMS.

The work in this division will be outlined at a later time.

D. IMPACT TESTS.

The work in this division will be outlined at a later time.

IV. REINFORCED CONCRETE COLUMNS.

The term column will here be used to mean a piece more than three diameters in length which is subject to compression in the direction of its length. The tests are intended to determine the principal deformations, the behavior of the column as loading progresses, the manner of failure, the maximum and ultimate loads, the tendency to crushing at the ends and the effect of variations in the end bearing, the relation of strength to the ratio of least diameter and length, and the effect of eccentricity of loading. The details of the series will be outlined at a later date.

1. Effect of longitudinal reinforcement.
2. Effect of hooped reinforcement.
3. Effect of combined reinforcement.

V. REINFORCED CONCRETE SLABS.

The slabs are to be tested supported at four edges and fixed at four edges. It is probable that special apparatus will have to be constructed for these tests. Variations in size and thickness of slab and in method and amount of reinforcement will be made. This work will be outlined at a later date.

TESTING WORK.

I. MATERIALS AND MIXING.

1. *Cement.* The cement will be American Portland cement of the best grade used on concrete construction. Particular attention will be given to uniformity of quality to ensure a basis for comparison of results. Tests will be made according to the standard method of the American Society of Civil Engineers and the American Society for Testing Materials. The description and requirements for materials and mixing will be made more definite and complete when the scope of the test is more fully settled and when more is known concerning what materials are available.
2. *Sand.* The sand will be sharp torpedo sand with grains well graded in size, containing not more than 30 per cent. voids and not more than 5 per cent. of clay.
3. *Aggregate.* In the tests to determine general properties of concrete and reinforced concrete several forms of aggregate will be used, broken limestone, broken trap rock, gravel and cinders. For tests to determine special relations and effects only broken stone will be used. In order to secure a more uniform material, crusher dust will be excluded from broken stone. The stone will be screened through a 1-in. screen and over a $\frac{1}{4}$-in. screen. In order to get more definite proportions the gravel will be screened in the same way.
4. *Mixtures.* In general a balanced mixture of mortar and aggregate will be used, the volume of mortar being from 10 per cent. to 20 per cent. more than the voids of the aggregate. Two grades of mortar will be used, rich and medium. This will make for the broken stone something like 1-2-4 and 1-3-6 concretes.
5. *Mixing.* The specifications of the American Railway Engineering and Maintenance of Way Association will be used to secure thorough mixing. Considerable preliminary experimental study will be needed before framing full specifications for mixing and packing in the molds in order to secure as nearly as possible the same results at different

times, at different places, and by different persons, and the percentage of variation thereby resulting will need to be determined.

6. *Consistency.* An amount of water to make a wet rather than a dry concrete will be used. In some tests three consistencies will be used,—moderately dry, moderately wet, and very wet.
7. *Tamping.* The amount and manner of tamping is to be gauged by the consistency of the concrete, but an effort will be made to secure density and uniformity in the concrete.
8. *Storage.* In general the test pieces will be moistened for three or four days and then be stored exposed to ordinary atmospheric conditions in rooms having a temperature of 65° to 75° F. during the time of year when artificial heat is needed. The conditions of abnormally dry atmosphere is to be avoided. A special series will be used to determine the effect of dry and hot atmospheric conditions.

II. TEST PIECES.

In fixing the dimensions of test pieces, a size is desired which is large enough to minimize so far as possible the effect of uncontrolled or unseen irregularities of construction and setting, and to make the measurement of deformations and other changes large enough to be accurately observed. At the same time the limits of the facilities of laboratories have been considered. Probably after principles have become better known, a few principal series should be repeated on a large scale. In addition to the test pieces named, it is considered highly desirable in order to ensure reliable results that at each of the laboratories where work is done several practice test pieces be made and that these be used in familiarizing those assisting in the work with the needs and difficulties of the tests but be not considered as counting in the final results. It is recognized that some variations from the form and size of test pieces here described may be necessary.

1. COMPRESSION. The standard compression test piece will be a cylinder 8 inches in diameter and 16 inches long. A facing of mortar $\frac{1}{4}$ inch thick will be put at the top and the bottom. Cubes of 6-inch edge will be used to enable a comparison to

be made with concretes used elsewhere. Preliminary tests will be made on cylinders of different lengths to determine whether the length of the standard cylinder should be modified and whether the quality of the concrete obtained corresponds to that made in the reinforced beam and column test piece.

2. TENSION.—The standard tension test piece will be a cylinder 8 inches in diameter and 32 inches long. 3 inches at each end will be made of mortar and eight or twelve bolts will be embedded in this, connecting the test piece at either end with a stiff head in which a pulling bar with spherical bearing is set in a manner similar to the method used at the University of Illinois.

For determining the effect of concrete upon the elastic properties of steel, a bar will be encased for part of its length in a concrete cylinder and the ends will project sufficiently to permit attachment of the extensometers and to permit the bar to be held in the testing machine. The cylinders will be of two or three sizes, perhaps 3, 4 and 6 inches diameter.

3. BOND AND ANCHORAGE.—For determining surface adhesive resistance, the bar will be laid on a block of concrete 6 inches long with one face embedded $\frac{1}{8}$ inch, and will project at one end sufficiently to allow the load to be applied. The block of concrete will be of such size and shape and have such bearing as to permit a direct pull on the bar.

For the general tests for bond the bars will be encased in a cylinder 4 inches in diameter and 6 inches long and one end will be flush with the end of the cylinder. Special forms of piece will be used for tests of anchorage.

4. BEAMS.—The standard beam test piece will be 8 inches wide, 11 inches deep, and 13 feet long. The center of the reinforcing bars will be 10 inches below the top of the beam, except where they are bent or inclined upward for a special purpose. The forms will be firmly braced to secure uniform cross section. During construction the concrete will be well spaded along the side forms to secure a smooth surface. The top will be coated with a thin layer of mortar to remove

irregularities. For beams of other than standard size special plans will be made.

5. COLUMNS.—The size and form of column will be decided upon at a later date. 10x10-in. section and a length of 5, 10, 15 and 20 diameters is suggested. Larger sections will be used for special tests. The arrangement and distribution of the reinforcement will require further planning.
6. SLABS.—The outline for the form, size, and manner of reinforced concrete slabs will require further planning.
7. MISCELLANEOUS TEST PIECES.—The forms of test pieces for shear tests and for volumetric and other tests will be outlined when the work has been more fully developed.

III. TESTING.

In order that uniformity may be secured and the results of tests made in different laboratories may be known to be comparable, it is important that common regulations be adopted. The making of these will involve consultation and discussion. What is here outlined is subject to change.

1. COMPRESSION.—Concentric loading is of prime importance in compression tests. Spherical bearing block, roller bearings, or hydraulic bearing block should be used. A thin layer of plaster of Paris will be placed between test piece and bearing plate and allowed to set under a light load. The extensometer gauge length will be 12 inches. The arrangement of extensometer will be such that flexural action in the test piece will be nullified as far as seems possible.
2. TENSION.—The arrangement for testing tension pieces will be such as to give a direct pull and avoid flexural stresses in the test piece. In general the extensometer gauge length will be 24 inches. The arrangement of the contact points and gauge bars of the extensometer will be such that the effect of flexural action in the test piece will be slight. Bars for use in test for effect of concrete encasing upon elastic properties of steel will first have the modulus of elasticity of the naked steel determined.

3. BEAMS.—The method of applying the load is an important consideration. One great defect found in many tests of reinforced concrete beams is the indefiniteness of the distribution of the load, and in some tests the loading used must have acted to strengthen the beams. As used in structures, reinforced concrete beams are subject to both uniform and concentrated loads, and tests should cover both conditions. The general standard loading selected has the load applied equally at two points, the one-third points of the span. This loading does not differ greatly in maximum bending moment and in shear at the end from the conditions for uniform loading and has the advantage for the measurement of deformations that the moment except for that due to the dead load is equal at all points between the two load points. Series of tests will be made with the load applied equally at points sufficiently numerous to approximate to the conditions of uniform loading and also series with concentrated loading. The beam supports and the method of applying the load must give good bearing and allow adjustment for warped condition of beams and for free changes in distances between these points. In general the extensometer gauge length will be about one-third of the span length. The general standard for test span will be 12 ft. Deflections will be observed for the middle of the span length.

4. MISCELLANEOUS TESTS.—The method of testing columns and slabs and of testing for shearing resistance is reserved for future consideration.

5. METHOD OF APPLYING LOADS.—Different methods of applying loads will give quite different results. The effect of continuous, progressive loading, loading released after each observation, and progressive loading with the load released two or three times should be investigated. The choice of a standard method of applying the load should be postponed until preliminary tests have been made, as the decision of this point is a matter of importance.

6. DUPLICATION OF TESTS AND NUMBER OF TEST PIECES.—In general one more test piece will be made than required for the series, the extra one to be used in case of accident to

another or of marked disagreement among the others. For compression, tension, shear and bond, five test pieces will be made and four will constitute a series. For beams, slabs and columns, three test pieces will be made and two will constitute a series. Some of the more important series of tests will be duplicated, the work being done in two laboratories.

7. AGE.—In general 60 days.

The number of mixtures of concrete to be used for any line of investigation is not always fully stated in the outline. Further attention will be given to this.

SUPERVISION AND ADMINISTRATION.

It is the plan to have these tests made in the laboratories of engineering schools, railroads, etc., which have facilities for the work, and which upon consultation express willingness to cooperate. It is expected that much of the work will be done as thesis work by senior engineering students and that this will be greatly supplemented by volunteer investigators. The expense of materials and transportation and of extra labor employed in making, handling and testing the test pieces will be defrayed from funds raised by the Committee on Ways and Means.

The general conduct of the investigation will be in charge of a committee of five members to be called the Committee in Charge of Tests. In the prosecution of the work it will be very necessary to know conditions and results and to insure uniformity of methods and correlation of work. This will involve considerable correspondence, travel, and supervision, and the committee should have suitable and sufficient assistance. An inspector will be employed who will be under direction of the Committee in Charge of Tests. He will aid in arranging for tests, in doing testing work, and in putting results in permanent form, and will consult and confer with the laboratories doing work. The inspector will be able to be of much service in formulating blanks, collecting existing data, and generally assisting in the investigation. Other help will be employed as needed.

The results of tests made at any institution may be used by the institution, but they shall not be published by students. Indi-

viduals connected with the laboratories may publish results with the consent of the Joint Committee on Reinforced Concrete.

The above outline of plan and scope of the investigation is somewhat tentative and is necessarily incomplete and in some respects indefinite. When it is known more fully what work will be undertaken, full plans and regulations may be made. It may not be feasible to carry out all the work outlined during the first year, and it is not unlikely that developments in the investigation will show the necessity of repetition and modification in succeeding years.

The sub-committee realizes the magnitude of the task proposed, but it desires to emphasize the importance of the undertaking and to express its belief that the results of such an investigation carried out in a thorough and comprehensive way would be of great value to the engineering world.

APPENDIX II.

SYNOPSIS OF THE RESULTS OF THE INVESTIGATIONS UNDER DIRECTION OF THE COMMITTEE ON TESTS OF THE JOINT COMMITTEE ON CONCRETE AND REINFORCED CONCRETE.

The results thus far obtained under the direction of the Committee on Tests are not as yet in shape for a definite report, since the work of testing has only recently been completed and the different laboratories have not had time to compile or study the results. A brief synopsis of the scope covered by the investigations will give some idea of the work undertaken and of the directions towards which the results may be expected to give information. Tests on concrete and reinforced concrete were made at the following technological schools on the topics indicated under the direction of the Committee on Tests of the Joint Committee on Concrete and Reinforced Concrete:

Harvard University.—Complex flexure. Work only recently started.

Massachusetts Institute of Technology.—Reinforced concrete columns, effect of heating and quenching. Beam tests. Strength of Tee beams. Shearing strength of plain concrete. Bond.

Columbia University.—Effect of high temperature on strength of concrete.

Cornell University.—Effect of position and shape of reinforcing bar for varying percentages of reinforcement.

University of Pennsylvania.—Tests in Bending and Compression. Coefficient of Elasticity. Effect of Repetition of Load.

Ohio State University.—Tests of various reinforced concrete beams with various percentages of round bars.

Purdue University.—Beam Tests. Effect of elastic limit of metal. Effect of amount of reinforcement. Time of appearance of cracks. Temperature changes of concrete.

University of Illinois.—Shearing strength of plain concrete. Effect of repetition of load. Effect of rest. Time tests. Effect

of adhesion and grip on elastic properties of steel. Complex flexures. Coefficient of elasticity of concrete. Abnormal concretes.

University of Wisconsin.—Reinforced concrete beams. Position after neutral axis. Best method of turning up reinforced bars. Compressive strength of concrete in cubes and in beams.

University of Minnesota.—Bond.

Iowa State University.—Shearing strength of concrete. Bond.

So far as practicable materials have been furnished the different institutions. Stone from Kankakee, Ill., and sand from Chicago, Ill., was shipped to Purdue, Illinois, Wisconsin and Iowa. For the eastern institutions local sand and stone were obtained. In nearly all of these tests a mixture of five different brands of Portland cement was furnished by the Joint Committee. The steel was furnished in most cases by the Carnegie Steel Co.

When the work for the year was undertaken it was expected that Inspectors would be appointed to visit the different institutions and aid in securing uniform methods, and be able to give the Committee full information concerning the tests. These inspectors were also to be present at the tests and aid in making up the reports. As no inspectors were appointed, this part of the work was not carried out. Late in the year arrangements were made by which Mr. Richard L. Humphrey, a member of the Committee on Tests, in connection with the investigation of Structural Materials by the United States Geological Survey, made a trip to the different schools where investigations were being carried on, and helped the Committee as inspector. As this work was not begun until May 20th many of the tests were already completed, but Mr. Humphrey was able to obtain valuable information concerning the methods of the tests.

Reports have been received from most institutions. These reports are now being gone over carefully, but the compilation and studies of the results has not proceeded sufficiently to admit of a report. A cursory examination of the work at the various institutions indicates that results of value may be expected along the following lines:

Effect of repeated application of a load on reinforced concrete beam;

Upon the deformation in the steel and in the concrete;

Diagonal tension cracks, their occurrence and method of prevention;

Heating of reinforcing bars and effect of rough or smooth surfaces on plain bars;

Effect of heating and of heating and quenching upon the strength of concrete;

Temperature changes in concrete relative to changes of atmosphere temperature;

General tests on bond;

Column tests;

Tee beams;

Modulus of elasticity;

Shearing strength of concrete.

Results of center loads incomparable with those for other loading.

Arrangements have been made for the compilation and critical review of this work, and it is expected that this work will be completed in a very short time.

Arrangements have also been made by which the co-operation of the United States Government has been secured, and the investigations which will be carried on during the coming year, with the various technological institutions will be under the joint direction and supervision of the Committee on Tests and the United States Government, all expenses in connection with these tests being paid by the Government.

REPORT OF COMMITTEE K ON STANDARD METHODS OF TESTING.

The object of the work of the Committee should be to make a careful study of the methods of tests employed in America, in England, in France, in Germany, in Austria, and in Russia, determining, as far as possible, what is the degree of accuracy that can be secured, with the methods in common use, as well as with those which they decide to recommend.

The sub-committees should make reports, giving evidence obtained from all the literature published upon the subjects, from the practice of the various testing laboratories in different parts of the world, and, as far as possible, from any special sets of tests that can be made for them. They should also report their recommendations, in the light of the evidence thus obtained, and in view of the degree of uniformity that it is, in their opinion, feasible to obtain throughout the countries named above.

List of Sub-Committees.

I. A sub-committee on the forms, the dimensions, the selection, and the preparation of tensile test specimens, and on the conditions necessary to secure correct testing machines.

II. A sub-committee to report upon the general requirements for the measurement of elongations for the purpose of determining the Modulus of Elasticity, the Elastic Limit, the Yield Point, etc., including the limits of accuracy attainable with short gauged lengths, especially, 2 inches, and 1 inch gauged lengths.

III. A sub-committee to report what results can be obtained from transverse test specimens.

IV. A sub-committee to report upon the requirements necessary in the case of compression tests.

V. A sub-committee on Impact tests.

VI. A sub-committee on tests of full size specimens.
VII. A sub-committee on methods of Chemical tests.
VIII. A sub-committee on Metallographic tests.
IX. A sub-committee on miscellaneous tests, as drifting, punching, nicked-bending, quenched and cold-bending, and torsion.

Details to be considered by the various sub-committees.

I.

(*a*) Different gauged lengths.
(*b*) Dimensions of cross-section, for round, and for rectangular sections respectively.
(*c*) Minimum distance between each end of gauged length, and beginning of shoulders.
(*d*) Modes of testing testing machines.
(*e*) Modes of holding test specimens.
(*f*) Effect of different speeds of testing.
(*g*) Proper manner of selecting, and of preparing tensile test specimens.

II.

(*a*) General requirements for the measurement of elongations for the purpose of determining the Modulus of Elasticity, the Elastic Limit, the Yield Point, etc.
(*b*) On how many sides, and on which sides of the specimens, should measurements be made?
(*c*) Degree of precision obtainable by each method.
(*d*) Degree of accuracy needed in different cases.
(*e*) Within what limits of accuracy can measurements be made upon shorter gauged lengths, especially on 2-inch, and on 1-inch gauged lengths?
(*f*) Degree of accuracy obtainable with different methods of holding; not only in the breaking strength, but also in the determination of Modulus of Elasticity, Elastic Limit, Yield Point, etc.
(*g*) Effect of different speeds of testing.

III.

(*a*) Forms and dimensions of transverse test specimens.
(*b*) Comparison of breaking strengths obtained with different forms and dimensions.
(*c*) What can be ascertained as to Modulus of Elasticity, Limit of Elasticity, Yield Point, etc., by means of transverse tests, and with what degree of accuracy?
(*d*) Comparison of results obtained from transverse tests, and those obtained from tensile tests.
(*e*) Effect of different speeds of testing.

IV.

(*a*) Effect of different ratios of length to diameter, in small lengths, *i. e.*, in ordinary compression specimens and not in columns.
(*b*) Effect of different kinds of compression platforms, in the case of different materials tested for compression.
(*c*) Lengths, and gauged lengths, needed to obtain measurements with sufficient accuracy to determine the Modulus of Elasticity, the Elastic Limit, the Yield Point, etc.

V.

No details will be specified here.

VI.

A. Tension.
(*a*) Eve bars.
(*b*) Counterbraces.
(*c*) Anchor bolts.
(*d*) Connecting rods in tension.
(*e*) Parallel rods in tension.
What measurements should be made to obtain average values of Modulus of Elasticity, Limit of Elasticity, Yield Point, etc.
B. Compression.
(*a*) Columns for bridges.
(*b*) Columns for buildings.
(*c*) Connecting rods in compression.
(*d*) Parallel rods in compression.
(*e*) Piers of Masonry.

C. Transverse. What measurements should be made, and how should they be made?
  (*a*) I beams.
  (*b*) Plate Girders.
  (*c*) Trusses.
  (*d*) Arches of steel, and arches of masonry.

D. Shearing.
  (*a*) If pure shearing can be obtained, how can it be done?
  (*b*) Riveted Joints.
  (*c*) Shafting.
  (*d*) Shearing in beams.

VII.

(*a*) Extent to which it is wise to include such tests in our recommendations.
(*b*) Degree of accuracy that can be obtained with different methods.
(*c*) Degree of accuracy needed in different cases.

VIII.

(*a*) Extent to which it is wise to include such tests in our recommendations.
(*b*) Degree of accuracy that can be obtained with different methods.
(*c*) Degree of accuracy needed in different cases.

IX.

No details will be specified here.

Respectfully submitted on behalf of the Committee,

GAETANO LANZA, *Chairman.*

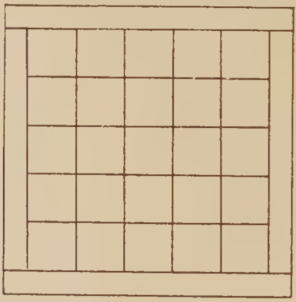
REPORT OF COMMITTEE M ON STANDARD SPECIFICATIONS FOR STAYBOLTS.

Your Committee submit the attached specification as a tentative one with the request that no definite action be taken upon the same until the next meeting of the Society.

The new features of the specifications are:

1. The method of manufacture is specified. This has been deemed advisable because experiments have conclusively proven that iron piled in the manner specified will give the best results in service.

2. A vibration test. It has not yet been proven that results can be duplicated in various machines nor that the particular method employed in testing give the most satisfactory results, but this test was specified as a basis for discussion and experiment



in the hope that the members of the Society most concerned with this matter will make experiments to definitely settle the advisability of vibratory tests, and the method of making it.

Specifications for Staybolt Iron of from $\frac{7}{8}$ in. to $1\frac{1}{8}$ in. Diameter.

Process of Manufacture.

All iron staybolts must be hammered or rolled from a bloom or pile having a minimum cross-sectional area of 45 square inches, and about 18 inches long.

The pile must be made up of a central core composed of bars of from ½-in, to 1-in. square and be covered on all four sides with an envelope ⅜-in. thick, as per sketch.

This pile must be rolled to a billet, allowed to cool, again heated, and then rolled into bars of the required dimensions.

Physical Tests.

Tensile strength—not less than 48,000 lbs. per sq. in.

Elongation—not less than 28 per cent. in 8 inches.

Reduction of area—not less than 45 per cent.

Double bending test—close in both directions without flaw.

Threading—permit of the cutting of a clear, sharp thread.

Vibration—shall stand a minimum of 6,000 revolutions when subjected to the following vibratory tests:

A threaded specimen, fixed at one end, has the other end moved in a circular path while stressed with a tensile load of 4,000 lbs. The circle described shall have a radius of 3-32 in. at a point 8 in. from the end of the specimen.

Inspection.

The iron must be smoothly rolled and free from slivers, depressions, seams, crop ends and evidences of being burnt.

It must be truly round within .01 of an inch and must not be more than .005 above, or more than .01 of an inch below specified sizes.

Selection of Samples for Test.

The bars will be sorted into lots of 100 bars each and two bars will be selected at random from each pile, failure of either of these bars to meet any of the above specifications will be cause for rejection of the lot which the tests represent.

Respectfully submitted on behalf of the Committee:

H. V. WILLE,
Chairman.

DISCUSSION.

Mr. Wickhorst.

MR. MAX. H. WICKHORST.—As regards the proposed specifications for staybolts, I very much object to having the method of manufacture in any specification, even the specification of any single railroad, and much more so in a general specification. In other words, apparently his tmethod of manufacture has been determined upon by the results of the vibration test. If that is the case, we ought to use the vibration test as the criterion, and not specify any particular method of manufacture.

The President.

THE PRESIDENT.—Evidence seems to be accumulating that for metals subjected to transverse stresses, anything which will distribute rather than localize the maximum stress, is of great importance. In the staybolt, if the method suggested by the Committee of having the metal rolled in small rods and then piled and rolled down to proper size, will produce this result of distribution of the strain, it is unquestionably of great import. We are inclined to think that the method suggested by the Committee is of value. On the other hand, we cannot help agreeing somewhat with Mr. Wickhorst that, as far as possible, specifications should be made without specifying methods of manufacture. Let the specifications designate the tests that the product is to stand, and the results that are expected from it, and let the manufacturers struggle with the method of producing these results.

Mr. Wille.

MR. H. V. WILLE.—As a general thing I object to specifying the method of manufacture. I believe, however, that an exception can be made of staybolt iron not only because it is a material for a special purpose, but also because the method specified will not require the manufacturer to purchase any special stock and will not require any special machining to roll the iron in the manner specified.

For these reasons the incorporation of the method of piling a staybolt iron is no more objectionable than specifying the ply of a hose or the amount of discard from rolled material and all the tests which we have made demonstrate that that method of

piling has a more marked influence upon the life of a staybolt, than any of the physical properties which it is customary to specify. For these reasons I am strongly opposed to the elimination of the paragraph. Mr. Wille.

Mr. J. A. Kinkead.—There is one question with regard to specifying the method of manufacture. Some staybolt makers have been making iron for fifty or seventy-five years. One concern started in 1793, and has its own method of piling, which they claim gives the very best service in locomotives, and they can furnish any amount of data on the subject to show conclusively that it does. Such manufacturers might object seriously to changing their methods at the instance of this Society. Mr. Kinkead.

REPORT OF COMMITTEE N ON STANDARD TESTS FOR LUBRICANTS.

Committee N, which was recently appointed, has held only a single meeting for purposes of organization. This meeting was held in May in the rooms of the Engineers' Society of Western Pennsylvania, Pittsburg, Pa.

There were present at this meeting Mr. Wm. M. Davis, Mr. John H. Jeffers, Commander W. H. Parks, U. S. N., Mr. Geo. H. Taber and Mr. Chas. E. Ward; the remaining members of the Committee, viz., Mr. P. H. Conradson, Mr. W. A. Converse and Mr. J. Howard Pew, being unable to attend.

Mr. Wm. M. Davis was elected permanent Chairman and Mr. P. H. Conradson was elected Secretary, but, owing to the latter's absence, Mr. Jeffers was appointed Secretary *pro. tem.*

After a general discussion of the proposed plan and scope of the work of the Committee the Chairman appointed the following sub-committees with instructions to report at the next meeting:

(*a*) On Threading Oils for Cutting Bolts and Pipe. Mr. John H. Jeffers.

(*b*) On the Best Methods of Making Viscosity Tests. Mr. G. H. Taber and Mr. C. E. Ward.

(*c*) On the Use of Friction Testing Machines in Determining the Actual Lubricating Value of Oils. Commander W. H. Parks.

(*d*) On Oil Analysis. Mr. P. H. Conradson and Mr. W. A. Converse.

(*e*) On Cold Test of Oils and Melting Point of Greases. Mr. J. H. Pew.

(*f*) On Specifications. Mr. Wm. M. Davis.

Respectfully submitted on behalf of the Committee,

WM. M. DAVIS,
Chairman.

REPORT OF COMMITTEE O ON UNIFORM SPEED IN COMMERCIAL TESTING.

Your Committee on Uniform Speed in Commercial Testing begs to report that at a meeting at which all members were present, it was unanimously recognized that a maximum speed in commercial testing was desirable, that is, a speed which, while facilitating the rapidity of output of work of a commercial nature in our testing laboratories, is still safe and reliable enough in everyday engineering practice. Anyone testing at a speed up to and including the recognized and established maximum limit could do so with the consciousness of being on the safe side.

Your Committee decided to make tests in order to arrive at some conclusion in the matter, but owing to the brevity of time at the disposal of the Committee, and other circumstances, nothing more than a preliminary report can be offered to this meeting by the Chairman. In order to profit by the experience and knowledge of other members of the Society, the Committee enlarged itself, with the approval of the Executive Committee, by choosing the Messrs. F. O. Bunnell, H. H. Campbell, Tinius Olsen and A. A. Stevenson, as additional members of the Committee.

While the speed results of tests in the appended tables vary from 1 to 5, 6 and 8 inches per minute, and are valuable for showing the results of extremes of speeds for commercial purposes, the differences of results of tests made with 3- and 6-inch speeds really came under consideration, since a speed of 3 inches or thereabout has been in practical use for commercial testing for a long time, and the question for your Committee to solve is practically whether the increase in difference of results, due to a 6-inch speed over a 3-inch speed, whatever that difference may be found to be, is in conformity with the requirements of the engineer. If it is found that the differences in results obtained with a 6-inch speed are not greater than the differences due to the errors which creep in unavoidable in all our commercial testing, and which errors are an undefined quantity, then it would seem that no objection could be raised to the establishment of a maximum speed.

The errors we encounter every day are caused by differences in the quality of the average commercial products of the same grade, plate, bar or forging, lack of knowledge of the laws governing stress and strain and the flow of metals, initial stresses set up in the metal by forging, rolling, heating and cooling, differences due to the greater or less accuracy obtained with different testing machines and personal equations, and the structural changes taking place within the test piece, as the test progresses from stage to stage, until rupture takes place. The first and last of these causes of errors, lack of uniformity of quality and changes in structure during test, are the ones with which your Committee is chiefly concerned.

Differences in quality of the average commercial product of iron and steel works, are unavoidable, and no matter how they may be lessened by the skill of the melter, heater and roller, these differences are there in varying degrees, and are wisely accounted for by the engineer in making his calculations and specifications. But since the results of testing are influenced by the structural changes taking place in the metal, and since original structural inequalities in the product intensify the effects of these structural changes due to testing, the question to what degree these complex changes in structure during test may possibly influence the results at higher speeds of testing, is one which deserves our consideration. Let us examine into what takes place when making a test of a piece of steel. We are dealing with two properties in the metal: viscosity and hardness. Viscosity finds its exponent in the degree of ductility, measured by elongation, and hardness is manifested by the degree of resistance offered to extraneous forces to tear the metal apart and is expressed in pounds of force to overcome this resistance. Viscosity is set in motion by zero-forces, acting through long intervals of time. Hardness becomes measurable by large forces acting through zero-time. Both these properties of metals are in constant relation and various degrees of interplay, while a piece of metal or a whole structure is under strain. When viscosity comes into play, or zero-force acting through long intervals of time, the particles of metal begin to flow, but have time to adjust themselves to new conditions and to break up slowly into smaller particles, but if time is not given for the particles to flow naturally, and large forces act through small

intervals of time, then the particles, after they have begun to slide, are forcibly urged over and across each other, and the shorter the time given, the greater the force necessary to assist the natural forces in pulling the pieces of steel apart. Hence, the property of hardness becomes more prominent with increase of speed, and at faster speed is greatly disproportionate to the property of viscosity, and its manifestations, expressed in per cent. of elongation, as is seen by a comparison in the tables of differences of speed.

Incidentally, this furnishes us with an argument in favor of higher speeds for commercial testing, without danger of infringing upon the factor of safety of the engineer. We all know that hardness of metals can be increased by mechanical means, but viscosity cannot thus be increased. As soon as we attempt to force a viscous substance into an accelerated flow, we get hardness, but not an increase in ductility, rather a decrease of it as manifested by the tendency to lower elongation at high speeds. Now here we come to a critical point in our investigation of high speeds for commercial testing.

Ductility is the engineer's indispensable factor, which must give pliability to his structure under vibratory forces of destruction. If then the degree of viscosity as expressed in per cent. of elongation, changes but little with high speeds of testing, it would indicate that the engineer's best friend remains a safe factor to him, and the increase in strength, due to high speeds of testing, is only an artificial phenomena, induced by conditions which will never occur under ordinary circumstances. Thus if the per cent. of increase of strength, due to speeds higher than was heretofore customary, is still within the limits of errors, which are unavoidable in commercial testing, and are provided for in specifications, then we can safely use such a speed for commercial testing.

On examining the results of the tests made we find that out of twenty cases of differences in per cent. of elongation, due to difference in speed, the per cent. of difference is less than one per cent. in thirteen cases, in steel as high as 45 per cent. and 60 per cent. carbon, and in the seven remaining cases, where the per cent. of elongation reaches one or more per cent., the elongation is lower in five cases of higher speeds and higher only in two cases. In one case, where the difference in strength between the 1-inch

and 8-inch speed reaches the unusual figure of 11,900 pounds, the per cent. of elongation is still only .3 of an inch lower in 8 inches than in 1-inch; this in a ½-inch bar of .60 carbon, where we might expect a larger decrease of ductility due to rolling.

In analyzing the differences of the averages in strength it is found that with boiler steel tested, the greatest difference between a ¾-inch and a 6-inch speed is 2,680 pounds, while the maximum difference between individual test pieces was found to be 1,970 pounds and 4.5 per cent. elongation, while the greatest difference, due to speed is 4.3 per cent. elongation.

Another factor remains to be considered briefly in affecting the results at high speeds, and that is the influence of the heat developed at higher speeds, due to the friction of the rapidly-moving particles, upon the breaking up of individual groups of particles of different densities, creating conditions of instability, such as will not occur to most structures, except where heat is applied or created by friction. To this frictional temperature is probably due the inappreciable difference in elongation, since application of heat is favorable to viscous deformation at as low a temperature as 100 degrees.

Interpreting then the results of the preliminary work of your Committee with the help and guidance of related scientific phenomenon, we may fairly assume a 6-inch speed of testing for commercial purposes of metal, of .45 carbon and less, as acceptable without detriment to reliability of results.

Through the kind intervention of Mr. C. R. Stewart, The Cambria Steel Company donated 24 12-foot steel bars of .45 and .60 per cent. of carbon, measuring from ½ inch to 1½ inches, to your Society for use in making experimental tests by your Committee.

Respectfully submitted on behalf of the Committee,

PAUL KREUZPOINTNER,
Chairman.

APPENDIX.

Table Showing Average Results of Tests.

Data furnished by the Homestead Steel Works, Cambria Steel Company, Tinius Olsen & Company, Chicago, Rock Island & Pacific Railroad and Pennsylvania Railroad Company.

Material.	Cross-Section. Inches.	Gauged Length. Inches.	Carbon.	Number of Tests.	Speed* In. per min.	Ultimate Strength. Lbs. per sq. in.	Elongation.
Boiler steel	1½ x ⅜ to ½	8	0.23	18	1	57,150	27.5
				16	3	60,080	21.8
				25	6	59,340	27.5
Round Bar Steel	½ to 1½ diam.	2.5	0.45	8	1	100,410	26.0
				6	3	104,850	27.3
				2	6	103,750	24.5
				6	8	108,000	27.
Round Bar Steel	½ to 1½ diam.	2.5	0.60	19	1	143,590	13.0
				19	3	148,000	13.8
				10	6	143,830	15.9
				9	8	151,820	11.6

* Speed is given to nearest even inches per minute.

DISCUSSION.

Mr. Kreuzpointner.

MR. PAUL KREUZPOINTNER.—Five members of the Committee are in favor of this report, and two disapprove of it. One of the members disagreeing with the report states that the difference between the 1-in. and 6-in. speeds would probably cause such a difference in accepting or rejecting material that it would not be advisable to use such a low speed. I beg to say that it was never the intention of the Committee, or myself personally, to disturb the present practice whereby commercial testing is carried on at 3-, 5- or 6-in. speeds. The idea is to establish a conventional maximum speed, with the understanding that below and at that maximum speed the engineer is within the safe limits of his calculations as far as the results of testing are concerned. If he uses a speed higher than the conventional one, he does so on his own responsibility and at the risk of controversy.

The tests made at 1-, 6- and 8-in. speeds were simply made as an experiment to see what the results of extreme differences of speed would show and the Committee never intended to consider anything less than a 3-in. speed, which, as you all know, has been the common speed for commercial testing these many years; consequently what we are trying to find is whether the differences in results between a 3-in. and say a 6-in. speed allows us at the present day to use a 6-in. speed to get through with our work, be still on the safe side and satisfy all parties concerned. If some testing laboratories should not have machines to test at a 6-in. speed that would not matter at all, since it would remain everybody's privilege to tes at whatever speed he please. The point is that the one who can test at a 6-in. speed, if this should be found the acceptable limit, can do so safely and without fear of controversy.

The objection of the second member was that differences in results need not be mentioned.

The Committee felt that it owed the Society some kind of a report, and the time having been too short to do more than what has been reported, it is distinctly stated that this is only a preliminary report of a few tests made at extremes of speed.

MR. WILLIAM KENT.—I believe it is all right to leave the yield-point out of specifications for tension bars, but in case the yield-point should be specified I think it important to state the maximum speed at which the testing machine shall be run until the yield-point is reached. It makes a difference in the apparent or recorded yield-point if the machine is run fast or slow, and one can make a big mistake in reading the yield-point if the machine is run too fast. I think the Committee should take that into consideration when reporting finally on the subject. **Mr. Kent.**

MR. C. R. STEWART.—In the tests we made at Cambria, we ran the machine according to our custom, at 1 in. per minute up to the yield-point. We then changed to the speeds given in the table up to 8 in. per minute, except, of course, in the case of the $\frac{3}{4}$-in. speed, which was the same from beginning to end. **Mr. Stewart.**

REPORT OF COMMITTEE P ON FIREPROOFING MATERIALS.

Committee P on Fireproofing Materials met on May 24, 1905, and effected an organization, with Professor Ira H. Woolson as Chairman, and Mr. Rudolph P. Miller as Secretary.

So far, only an outline of the lines along which the Committee will work has been laid out. It is the sense of the Committee that its work for the present should be limited entirely to formulating standard tests to which fireproof materials should be subjected. It is proposed to establish such standards for the testing of the following forms of construction: Fireproof floor-systems, fireproof coverings for columns, fireproof partition constructions, and such other forms as may, from time to time, be suggested.

The Committee will for the present limit itself to the accumulation of data on methods of tests and results, and where it is thought that the information is sufficient, an endeavor will be made to establish standards.

Respectfully submitted on behalf of the Committee:

IRA H. WOOLSON,
Chairman.

RUDOLPH P. MILLER,
Secretary.

REPORT OF COMMITTEE Q ON STANDARD SPECIFICATIONS FOR THE GRADING OF STRUCTURAL TIMBER.

The following is submitted as a preliminary report of Committee Q, on Standard Specifications for the Grading of Structural Timber. In view of the fact that this Committee was not organized until this spring, and owing to the impossibility of getting the various members together, little has been done beyond the organization and statement of the problem. An informal discussion of the questions involved has taken place, both personally and in writing, and as a result of this, the following preliminary discussions are presented:

It is believed that the time has come for a comprehensive study and analysis of the grading of structural timbers, so as to arrive at a general understanding of the qualities of the various woods used for structural purposes, in order to standardize as far as possible, for the use of lumber manufacturers on one hand, and architects and engineers on the other hand, the various grades and qualities of woods. As indicated in the recent issue of a lumber journal "one of the most important practical results of such a study would result in giving to each wood all the credit, with respect to strength and durability, to which it is entitled and thus reducing the enormous waste that now results, even in the practice of the most competent engineers, from a lack of a thoroughly reliable system of grading, inspection and strength determination."

It is proposed to treat the subject under three general heads:

1. Definition of Structural Timbers.

It will be necessary to define what is to be understood by structural timbers, and to indicate the various uses to which different kinds of wood are put as structural timbers.

2. A Standardization of Trade Names.

The Committee considers that one of its most important functions will be to definitely establish a list of common names of timber in use in this country. There is probably no one factor

in the specifications for wood which is in such a chaotic condition as the common names applied to commercial timbers in the various parts of the United States and abroad. This is well shown by the names used for Douglass Fir, one of the most important of the structural timbers to be considered, which is known as "Yellow Fir," "Red Fir," known locally in Washington as "Fir," known east of the Cascade Mountains as "Washington Fir," known in California as "Oregon or Puget Sound Fir," known in the Hawaiian Islands as "Norwest," and known in the Asiatic ports as "West Coast." The Committee proposes to establish a list giving the most approved names, together with such local and foreign terms as are in use.

3. GRADING.

Grading as now understood consists essentially in the specification of three factors:

a. A definition of standard defects and to what extent these standard defects shall be admitted into various grades.

b. A determination of sizes, that is, in length, width, and thickness.

c. In certain instances the functions to which the material is to be put are to be specified.

The work which the Committee proposes to undertake will be of such a character as to include investigation of existing grading specifications, a discussion of their meaning, and the variation or possible elimination of distinct sets of grading rules now in use for the same kinds of timber, the establishing of a uniform system of nomenclature in grading, and lastly an investigation as to the possibility of the adoption of a universal system of inspection and grading.

To consider these subjects somewhat more in detail:

1. *Standard Defects.*—The defects used in the determination of grades are more or less understood as published in the various inspection rules of lumber manufacturers' associations. They serve as a basis for a classification and standardization. It is suggested that these defects be considered as natural defects and mill defects. Included in the consideration will be the effect which the various defects have on the strength and durability of the material. The influence which a given defect will have for different kinds of material will likewise be considered.

2. *Grading.*—The Committee proposes to consider the advisability of establishing specifications both for grading and for grades. In the standardization of sizes the Committee will probably do no more than classify existing usage and to compile the most reliable data of factors determining sizes, such as strength and use, now at hand. The most important points to be considered will be the comparison of present grading rules used by different associations, and lumber manufacturers, with the purpose of determining whether it will be possible to establish some universal rule for grading, as applying to timbers in general, such as "Clear," "Select" and "Common," with the addition of such special grades as may be warranted by special manufacture, or should this be found impracticable, to establish grading rules which may be applicable in general terms to all classes of timber, so as to enable the engineer and architect to compare in a more or less accurate manner, comparative values of the different timbers. This will enable an architect or engineer in New York, for instance, to draw up specifications for buildings in Denver. It will enable him furthermore to make specifications readily intelligible, not only to himself, but to the lumber manufacturer. It would result in a very material simplification of the present system of specifications.

The Committee begs to point out that the problem is a large one, and one which should receive the most thorough consideration, not only from members of this Society, but also from engineers and lumber manufacturers and associations, all over the country. It would ask for authorization to present these various points for consideration to the different lumber manufacturers' organizations and to invite a broad discussion of the problems involved, through the technical press.

It is recommended that the work of the Committee be directed to the final end of issuing a handbook covering standard grading rules for the various classes of lumber, for the use of manufacturers, architects, and engineers. That is, to have a standard set of specifications which might be entitled, "National or Universal Grading Rules and Specifications."

Respectfully submitted on behalf of the Committee:

HERMANN VON SCHRENK,
Chairman pro tem.

DISCUSSION.

Mr. von Schrenk.

MR. HERMANN VON SCHRENK.—I should like to add a few words as to the scope and purpose of the proposed investigation. I have talked the subject over with various manufacturing associations and various groups of engineers, and I am sure that as far as the grading of structural timber is concerned we cannot magnify the arduous character of the work too much, particularly when you remember that, instead of having one kind of timber, we have fifteen or twenty large groups of timber, differing not only among themselves but differing in the kind of tests to be made to determine their value. These tests have been very crude and to a large extent different for different materials, and when first stated these problems seem very chimerical to lumber manufacturers who are apt to shake their heads and smile.

I want to read the following brief extract from an editorial comment, in last month's issue of the *American Lumberman*, which will give you an idea of the point of view which the manufacturer takes as to the object this Committee has and the ends which it will serve:

"It is announced that a meeting of Committee Q of the American Society for Testing Materials will be held at Atlantic City, N. J., June 29 and 30. This Committee will take up the question of evolving and securing the adoption of a universal system of grades for structural timber for the benefit of engineers and architects. Under existing methods of inspection, it is claimed, much confusion obtains, and the grade, of itself, does not give the architect or the engineer a working knowledge of the actual quality of the material. Thus, for example, timber of a certain grade in yellow pine will serve a purpose that Norway timber ostensibly of the same grade will not fill. In other words, it is charged that architects and engineers must specify a class of material with whose quality they are familiar, or enter into an investigation of the merits of any other wood which it may be decided to use. The Committee having this matter in charge desires to do away with this confusion by perfecting a system of grades and inspection by which timbers of all kinds can be classified under certain common grade names and which grades will be

so perfected in relation to the various woods that a given grade will represent equivalent qualities in every used wood. The question is one which should receive the serious attention of all lumber manufacturers, especially in view of the fact that the plans of the Committee may be extended to include all classes of lumber. So much has been said latterly in regard to grades and grade definitions that this proposition comes in the nature of a climax. It is purposed to work into practical form theories which have been floating around in the trade and among architects and engineers for years. Confining the question for the moment to structural material, it is evident that even that branch of the subject is of no small proportions. Into a solution of the question must enter a study of the normal strength of the various timbers, the defects peculiar to each kind of wood and the effect that these defects have on strength and durability, and, besides, the sizes of the materials must be taken into consideration. The *American Lumberman* may be pardoned for a little scepticism as to the probability of such an ideal being realized at an early date, but in any event a consideration of the subject is opportune and should be worth all it would cost. Methods of inspection and the determination of the value of woods in their application to use have in the past been largely empirical, while those who have been attacking these problems from a thoroughly scientific standpoint have not yet progressed far enough to make the results of their work of general value. One of the most important practical results of such a study would be to give to each wood all the credit in respect to strength and durability to which it is entitled, and thus avoid the enormous waste that now results, even in the practice of the most competent engineers, from the lack of a thoroughly reliable system of grading, inspection and strength determination." **Mr. von Schrenk.**

There is one other point I should like to speak of. The position the Committee has decided to take, as far as I am able to gather from the various members, as to distinction of grades and specifications for grading. Grades to-day mean standards which have been adopted, that is, commercial standards which have been adopted by the lumber manufacturers. They are almost universally matters of trade judgment. When we remember that we have fifteen or twenty such associations, each adopting grades or standards of its own for a particular class of material, largely for the purpose of simplifying business relations with the consumer, you can see any material study further than the determination of strengths would be out of the question so far as this Society is concerned. But it is different with the question of specifications for grading.

These are some of the problems chosen for analysis on the part of this Committee, and you can foresee that the field is an

Mr. von Schrenk. enormous one. It is a useful piece of work, and one that will be valuable to the Society.

Mr. Kent. MR. WILLIAM KENT.—I do not think this report should pa s without some remark. I think this Committee should be congratulated on the excellent statement it has made. When we consider that timber as found in the market is worth anywhere from ten to one hundred dollars a thousand, and that in the next ten or twenty years these prices are going to be doubled, and timber is going to become a precious article, it is a matter of millions of dollars to the people of this country to have proper grading. I hope the Committee will go right ahead wi h the preparation of a system of grading timber, for it will be worth millions to the United States.

Mr. Woolson. MR. IRA H. WOOLSON.—I am particularly interested in the question of lumber specifications; I met the thing in rather a practical form this past year. In class study or practical determination of the varieties of timber, I undertook to teach the students standard lumber specifications. I found it was very difficult to teach them the proper grading of lumber according to the various specifications. I had to give it up. I called their attetion to certain ones, such as those of the Southern Lumber Association, and gave them an idea of what was in the market. I think the Chairman is to be congratulated upon the effective way in which the Committee has organized and outlined its work. But they have plenty of work ahead of them. There is no doubt of that.

Mr. Hatt. MR. W. K. HATT.—In the case of timber, after one specification has replaced the many, this one will still be incomplete, especially for the grading of such structural timbers as stringers and carsills. The present specifications usually rule that structural timbers shall have certain features, and "no defects that will materially impair their strength and durability." This latter clause leaves open the question of what constitutes a defect that will impair the durability or the strength of a stick. Such specification should be improved by specifying the defects which will throw a stick from one grade to a lower. This is a matter to be determined largely by tests, and the Forest Service will in a short time have such tests.

In addition to matters of this kind we find certain clauses of specifications handed down through custom from one specification

to another. For instance, the clause eliminating bled long-leaf pine from use is one of this kind. Again the clause stating that all timber must be cut from live, growing trees is very often an unnecessary clause. The value of the Committee's work along the line of structural timber will lie in making such specifications more definite and more in accordance with present knowledge. **Mr. Hatt.**

REPORT OF COMMITTEE R ON BOILER INSPECTION.

Professor Spangler, Chairman of Committee R on Boiler Inspection, has delegated to me the duty of reporting on the present status of boiler legislation in the United States.

At the meeting at the Delaware Water Gap in July, 1903, I called attention to the necessity of cooperation by this Society with the American Boiler Manufacturers' Association and the Association of American Steel Manufacturers in a movement to improve the United States steamboat inspection service in so far as it related to boilers and their appurtenances.

The matter was favorably referred to the Executive Committee and assistance duly rendered. Later in 1903 and in January, 1904, committees from the two associations mentioned met in Washington and discussed the subject fully with the Board of Supervising Inspectors and with the Secretary of Commerce and Labor. This department, then but recently formed, had just assumed charge of the steamboat inspection service, and Secretary Cortelyou, while favorably impressed with our presentations, was not ready to commit himself. The Committee presented a bill to the Fifty-eighth Congress, which was argued by Mr. Wm. H. Fletcher and the writer before the Committee on Merchant Marine and Fisheries in the House, and favorably reported on. But about the same time Secretary Cortelyou introduced a bill of his own, and, desiring to avoid conflict with the Executive, we did not further push our bill. The Cortelyou bill passed the Senate but failed in the House.

The following summer the disaster to the "General Slocum" luridly illustrated the deficiency of the steamboat inspection service, and the Board of Supervising Inspectors were especially called together for complete revision of their rules and suggestions as to changes in the law. Naturally their work was mainly in the direction of safety appliances as regards dangers by flood and fire. But their very voluminous report to the present Secretary of the

Department of Commerce and Labor, Mr. V. H. Metcalf, contained much matter concerning the construction of boilers, etc.

Secretary Metcalf called a meeting of all interests affected for January 16, 1905, to discuss and criticize this proposed revision. This meeting occupied a whole day from about 9 A.M. until 7.30 P.M. The greater part of the day was spent in discussing life preservers, inspection rules, number of passengers, fire protection, etc. But late in the evening Mr. Hartley of Philadelphia, a member of Committee R, Mr. Rees of Pittsburg and the writer obtained the floor for the discussion of the boiler matter. Certain exceptions to the steel specifications were discussed, as also certain provisions in regard to tubes. Mr. Rees pointed out especially the troubles arising from ignoring the effect of the substitution of the modern shape of test-piece for the one formerly used by the supervising inspectors, and showed differences in tests on the same material running from 5,000 to 15,000 lbs. per sq. in. The consequence was that by retaining the requirements as to tensile strength which had been found to be correct with the old test-piece, steel had to be made by the manufacturers much too high in carbon in order to show the same tensile stength with the present one. There were a number of other matters brought out which space will not permit me to report here.

In an address to the plate manufacturers in Pittsburg, February 25, 1905, I went fully into these details, and found that our work had their entire approval.

Our Committee obtained the closest attention from Secretary Metcalf and Assistant Commissioner A. K. Smith. The latter gave us individually several hearings by special invitation, and many of the points we brought forth were decided by him in our favor. The result of the whole discussion was favorable to the general idea of a bill for the revision of the boiler laws as advocated by this Society and the two associations mentioned. The wide range and mass of detail of the discussion convinced the officials that the subject was too broad and deep to be settled in a few public meetings.

There is good ground for the belief that a bill similar to the one of 1903 could be prepared, which would receive the confidence and active support of the Department. The late bill, as most of our members will remember, was for creating a commission of

experts, representing all the great interests involved in boiler and ship construction, which commission should issue first a preliminary report to the Secretary of Commerce and Labor, copies of which to be furnished by the Department to any one wishing to discuss it in writing. After giving a reasonable time for such discussion, the commission was to meet again and make a final report in regard to the complete revision of the steamboat inspection service so far as it related to the actual construction and management of steamboats and their machinery, and to draw up a bill for passage by Congress.

It has, however, now become apparent that a great many other details of the steamboat inspection service require revision as much as those mentioned, and that, therefore, the scope of this commission must be enlarged so as to embrace them all.

The code of laws and the rules based thereon which govern the whole steamboat inspection service, are largely archaic and do not represent the present best practice in any of the numerous details involved. A thorough revision is, therefore, an absolute necessity. But so much good has been accomplished under the old laws and rules by conscientious and capable inspectors, that the history and results of the service as embodied in the various annual reports of the supervising inspector general should form a very important part of the material to be scrutinized and sifted by the expert commission.

I trust this Society will again instruct its Executive Committee to cooperate with the American Boiler Manufacturers' Association and the Association of American Steel Manufacturers in formulating and urging this necessary revision.*

Very respectfully submitted,

E. D. MEIER.

* Favorable action was taken on this suggestion.—ED.

SOME CAUSES OF FAILURE OF RAILS IN SERVICE.

By Robert Job.

For a number of years a careful study of causes of rail failures has been made by the Philadelphia and Reading Railway. The method followed has been in the case of each failure to forward a portion of the rail showing the defective condition to the Test Department with a form giving information regarding the manufacture and service of the rail. An investigation then followed to determine the cause of the failure. In a general way it may be said that when failure occurs owing to fracture, excessively rapid rate of wear under given conditions, or crushing down in track, the poor service is generally due to one or more of the following causes, viz., (1) Pipes in the steel, (2) presence of a considerable proportion of blow-holes, (3) excessive segregation, (4) coarse granular structure, (5) rough handling. In the first case the defect is readily shown by the appearance of the fractured end with its unwelded surfaces, and upon buffing off a section of the rail, the extent of the pipe is generally clearly shown, even without etching, as in Fig. 1.* In such case the steel is in a seamy condition, and the layers readily split apart or crush down upon comparatively slight pressure, and indication of the unsoundness is usually given after a very short service. This general type

Fig. 1.—Pipe in Steel. Section polished but not etched.

*Acknowledgment is made to the *Railroad Gazette* for the cuts used in this paper.—Ed.

is caused by failure at the mill to crop ingots down to sound steel, and such a rail is nearly always derived from metal from the top of an ingot, and almost invariably fails when tested under the drop test. When the mill inspection is watched closely and when it is seen that the test butt for the drop test is always taken from the top of the ingot, failures due to such pipes are relatively rare.

A defect of this character is one of the most dangerous which can be present, since it is liable to result in sudden crushing under light pressure, and consequently it should be guarded against most carefully at the inspection.

The second cause of failure, viz., presence of considerable proportion of blowholes in the steel, is probably the most common defect under present mill practice and the one which causes the largest number of failures in service to-day.

FIG. 2.—Wing Rail, Unsound Steel. Service five weeks.

Such rails usually do not fracture after a very short service unless the extent of the blowholes is very pronounced, but the defects are generally noticed by the gradual mashing down of portions of the rail, accompanied generally by flowing over at the sides of the head, and the track men are apt to complain that the rail in question is "too soft," or that it has numerous "soft spots." Analysis proves, however, that the metal is not softer than that in other rails adjoining the defective one, but upon polishing and etching the section lightly with iodin or other medium it will be found that the steel is unsound, or in other words, that blowholes, slag and other foreign matter have prevented thorough welding of the steel and have resulted in a number of seams which break up the solidity of the metal and permit a slipping apart of the unwelded surfaces under moderate pressure, causing final fracture or crushing. In some cases this condition is caused by presence of slag and of

oxides in the steel, but in the greater number of instances it is simply due to blowholes, and relatively little slag or oxide is present.

Fig 2. represents the heel of a wing-rail of a frog, of the following analysis:

Carbon	.63
Phosphorus	.137
Sulphur	.078
Manganese	.874

This rail crushed down in service upon another road into the condition shown, in less than five weeks. Figs. 3 and 4 represent a batch of rails which mashed down in a few months upon another road to the contour represented by the dotted line. The unbroken line represents the template, and the large black areas indicate holes in the steel which were formed by the elongation of the metal upon the top of the rail when the failure began. When this section was polished there was no indication of an actual pipe, but upon light etching the cause of the weakness is very evident, showing that the steel is so thoroughly unsound and porous that rapid crushing was possible.

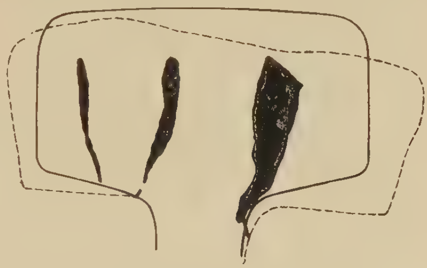


FIG. 3.—Contour of Fig. 4 after five months' service.

FIG. 4. — Unsound Steel. Five months' service.

The composition of this rail was: carbon, .82; phosphorus, .102; manganese, .88; sulphur, .053; and the heat average was: carbon, .59; phosphorus, .075; sulphur, .074; manganese, 1.06.

It is thus seen that a marked segregation was present as well as great unsoundness, and it is evident that the cropping at the mill had been insufficient to get to sound and reasonably homogeneous metal. These rails were furnished under the mill's own specifications and guarantee.

The tendency of some rails to flow over and form a "lip" has been referred to, and this freqeuntly is attributed to mere softness of the steel. Our experience has been that a rail with carbon as low as even 0.33 per cent. will not flow over under exceedingly heavy traffic, provided sound steel is present, with granular form fine enough to render the metal tough and strong; and in every instance of flowing over or of breaking down of the side or corner of the head, we have found presence of blowholes or other unsoundness near the surface or corners of the head of the rail, generally within one-eighth or one-quarter of an inch of the surface, whereas in the cases in which the rails have sustained long and heavy traffic we have found comparative freedom from such defects. A case of this kind which was investigated a couple of years ago will illustrate the point.

A number of rails from a single rolling had mashed down in track after two months' wear to the general form represented by Fig. 5, the broken line representing the template. These defective rails were upon curves and upon tangent, and were from various heats throughout the rolling, but rails from the same heats and immediately adjoining the defective rails were unaffected by the traffic.

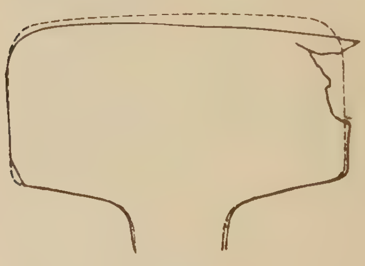


FIG. 5.—Contour of Fig. 6 after two months' service.

It was found that composition had nothing to do with the failures, but upon polishing and etching the sections we found in the cases in which flowing and splitting occurred, that the steel was unsound, as indicated in Fig. 6, while the rails adjoining which were in good condition were of sound steel as indicated in Fig. 7.

We have also investigated a considerable number of rails to

etermine whether or not the form of section exerted an influence upon the tendency to crush in service, and it has been clearly proved that ability to withstand crushing under heavy service is due not so much to any particular form of section, as to the relative freedom from unsoundness in the metal. In connection with this question an examination was made about a year ago upon a lot of rails which were removed from main track and relaid in branch lines. The section had a rather deep head with contour approximating that of a wheel flange. Practically no flowing and no crushing was ound in these rails after 15 years' service, while a number of rails of the Am. Soc. C. E. section laid in adjoining parts of the same track had crushed and otherwise failed in a very few years. The composition of the different lots showed comparatively little variation, but in the case of the rails which crushed in service we invariably found unsoundness, of the general type indicated by Fig. 6, whereas in the good rails the steel was practically sound within one-half inch of the surface of the top and sides of the head. In other words, the good service was due mainly to the greater care

FIG. 6.—Unsound Steel. Service two months. Mashed down as shown in Fig. 5.

FIG. 7.—Sound Steel. Service two months. Rail next in track to Fig. 6. No tendency to mash down or flow over.

exercised in the manufacture of the earlier rails and their consequent relative freedom from unsoundness.

Up to this point we have made little mention of granular structure of the metal, and it may he inferred that this has little influence upon the permanency of the rail in track. On the contrary we have reason to regard a uniform fine granular structure of high importance both in reducing rate of wear and in cutting down liability of fracture, but it is an unfortunate fact that the very best of steel as regards granular form or composition may be completely and quickly ruined, from the standpoint of efficiency in track or in other words, as to its value as a rail, by failure in manufacture to ensure reasonable freedom from unsoundness. This, to our mind, is an integral point in the manufacture of rails, for if any material degree of unsoundness exists in the rail within a distance, say, of $\frac{1}{4}$ or $\frac{1}{2}$-in. from the head or sides and more particularly near the upper corners, unsatisfactory service under heavy traffic is almost certain to result regardless of the composition or method of rolling. Such, at least, has been our invariable experience. As to injurious segregation, we find that relatively few failures in track are due to this condition. If ingots are not properly cropped, or if they are allowed to remain in the furnace with the interior of the ingot in a liquid condition for an excessive time, segregation of course results; and if the test butt from each heat is taken, as should invariably be done, from the top of the ingot, badly segregated rails will fail, and consequently under such conditions careful guarding against segregation is as much for the interest of the manufacturer as for that of the consumer. Fig. 8 represents one such rail which failed under the drop test, and the extent of

FIG. 8.—Segregated Rail. Broke under drop test.

the segregation is shown by the fact that the proportion of carbon at the outside averaged 0.49, while at the centre of head borings taken with a quarter-inch drill averaged 0.76. Also it will be noted that blowholes extend all along the top of the head. Such cases as this are however rare.

Under "failures due to rough handling" we have found a considerable number from time to time. The initial fracture may, of course, occur either at the mill at straightening presses or in loading into high side cars and letting fall upon other rails five feet or more below, or in letting the rails fall from the loader six or seven feet upon the ground, and the same thing, of course, may occur after receipt of the rails in unloading unless they are skidded out or otherwise gotten to the ground without any considerable shock. Careful inspection will remedy this condition. A fracture of this type is characteristic. It begins generally across the base of the rail and extends a short distance into the web, then it works along the web, sometimes, for a distance of six feet or more, with the face of the fracture in a plane at right angles to a vertical line down through the rail, and the steel finally snaps off up through the head.

A fracture due to this cause can generally be identified at a glance and can be distinguished from a fracture caused by pipes, since the latter extend with the unwelded faces more or less parallel with the contour of the rail.

To sum up, the results of our investigation indicate that the greater part of the difficulty which occurs to-day with rails under heavy traffic is due to unsound condition of the steel, a condition which existed in comparatively slight degree in the earlier rails.

There has been a marked improvement in practice at some of the mills over that generally prevalent a decade or two ago, and this has resulted at such mills in producing a much finer granular form throughout the section and hence a tougher and better wearing rail if only the metal were sound, but, unfortunately, in the essential element of soundness of the steel there has been direct retrogression, making it appear that the main attention in the manufacture has been fixed upon quantity and not quality of the output.

DISCUSSION.

The President.

THE PRESIDENT.—It occurs to me to ask what influence the size of the ingot which has been characteristic of the last fifteen years, has on the quality of steel in rails. We all know that the larger the ingot, the greater the segregation, and we have many times queried, whether more successful rails would not be obtained, from the same grade of steel, if it were cast into much smaller ingots, than is now obtained with the customary large ingot. We recently examined twelve rails drawn from track which had failed within the first six months after they were put down new. The failures consisted in splitting at the ends, breaking down of the head in certain parts of the rail, and in some cases a piece of the head three or four feet long breaking off. In the case of every one of these twelve rails, an analysis showed serious segregation. We were forced to the conclusion that in these rails, an attempt had been made to utilize the whole ingot in making rails, and we are confident this is a much more serious cause of failure than is generally believed.

Mr. Job.

MR. ROBERT JOB.—We have had instances of split rails such as described by the President, and have often found evidence of segregation, but in every case of such failure which we have investigated the steel proved to be radically unsound, and thus unwelded, and hence permitted crushing under relatively light pressure.

We have also examined rails which have been as badly segregated as those just mentioned, and in spite of it have given good service, but in these cases the steel was relatively free from unsoundness, particularly within one-half inch of the bearing surface. Hence it seems clearly indicated that lack of soundness is the main condition to be guarded against; it is the *bête noir*—from the consumers' standpoint—of present practice. Without it there would probably be few, if any, split rails, no slivered or flowed over rails, and no "soft spots," or mashing down. Moreover, with unsoundness removed, segregation to an injurious extent would be almost impossible.

RAIL SECTIONS AS ENGINEERING STRUCTURES.

By P. H. Dudley.

The mechanical properties, of stiffness and strength of a section, increase in a rapid ratio as the height is augmented, as shown by Table No. 1.

Table No. 1.

Weight of Section in lbs.	Height in inches.	Width of Head.	Moment of Inertia 4th power inches.	Moment of Resistance Cubic inches.
60	4.0	$2\frac{1}{4}$	12.0	6.7
65	4.5	$2\frac{3}{8}$	16.0	7.8
80	$5\frac{1}{8}$	$2\frac{21}{32}$	28.5	11.4
100	6.0	3.0	48.5	16.6

The 80- and 100-pound sections become more efficient engineering structures than the 60- and 65-pound which they replaced, by inducing a longer distribution of the passing wheel loads to the cross-ties and ballast, and lessening the deflection under the wheels. A greater portion of the wheel effects is absorbed by the constraining negative bending moments in the wheel spacing, reducing the positive moments under the wheels. This favorable action for a smoother running surface in the general depression under the wheels, however, increases the wheel-contact pressure intensity per square inch in the bearing surface of the section, and imposes a greater burden upon the metal of the entire head.

The stiff sections for a given unit-fiber stress carry larger bending moments than the limber rails and therefore are more efficient engineering structures for heavier axle and total loads.

In the 80- and 100-pound sections nearly the given maximum moments have been obtained in tests.

Unit-fiber stresses in tension from 0 to 30,000 pounds are those which occur daily under present locomotives, with some stresses of the higher figures and liable from a flat wheel to be exceeded.

Large unit-fiber stresses have been common since steel has been used for rails, for the limber sections had frequent sets, which indicated they were stressed beyond their elastic limits.

Under 65-pound rails in a yard track, a unit-fiber stress has been measured of 56,000 pounds.

The elongation for the unit-fiber stresses in Table No. 2, would be 0.00034, 0.00067, 0.001, and 0.00134 in. respectively, for the modulus of elasticity at 30,000,000 pounds, summer temperatures, though it is higher for the winter.

TABLE NO. 2.

POSITIVE BENDING MOMENTS IN INCH-POUNDS FOR THE GIVEN UNIT-FIBER STRESSES PER SECTION IN TABLE NO. I.

Section.	10,000 lbs.	20,000 lbs.	30,000 lbs.	40,000 lbs.
60 lbs.	67,000 I. lbs.	134,000 I. lbs.	201,000 I. lbs.	268,000 I. lbs.
65 "	78,000 "	156,000 "	234,000 "	312,000 "
80 "	114,000 "	228,000 "	342,000 "	456,000 "
100 "	166,000 "	332,000 "	498,000 "	664,000 "

The height of the section is increased to augment the mechanical properties, of stiffness and strength. This has a tendency to reduce the unit-fiber stresses in the base of the rails, but the subsidence of the road-bed under the wheel loads, the looseness of the cross-ties in the ballast, and the rails under the spikes, cause the bending moments carried by the stiff rails, to exceed those by the limber sections for the same wheel loads, though the percentage distributed per individual cross-tie is less. This increases the intensity of the wheel-contact pressures in the bearing surface. The wheel loads also have been doubled on the stiff rails, over what they were on the light sections, and the metal in the bearing surface therefore sustains two and three times the burden required by the former limber sections. See Vols. III and IV of the Proceedings, for Unit Fiber Stresses and Bending Moments.

To carry the stresses and distribute the wheel loads, the rail section has the top of the head or bearing surface shaped for the wheel treads, to receive their pressures and distribute the loads to the cross-ties, ballast, and road bed. The side of the head of

the rail is the guide for the passing wheel flanges, while the entire section becomes the girder to distribute the wheel loads.

The metal in the rail section has three functions to perform to receive, support, guide and distribute the wheel loads of the passing trains. 1. The metal in the bearing surface sustains its loads principally by its properties of cubic elasticity, and should be sound and homogeneous. 2. The side of the head resists abrasion of the wheel flanges by its toughness and tenacity. 3. To distribute the loads by the entire section its linear elasticity is exercised.

The factor of safety in the girder determines what physical properties may be used for the bearing surface and guide.

The metal in the head of the rail must receive and sustain the wheel contact pressures by its cubic elasticity, and distributes the loads through the section as a girder, by its linear elasticity.

The distortion of the rail head in service shows that the steel has low limits of cubic elasticity, and is not homogeneous. (See Figs. 1 and 2.)*

When the steel is solid, sound and of fine texture, the head does not become distorted under the service, though it wears in the bearing surface and on the side. When the ingot is unsound and spongy, then the head flattens and crushes under the wheel treads. Rails from the top of the ingots, where by liquation the upper portion contains a higher percentage of carbon and phosphorus, the central core of metal is not sound and strong, but fragile, and does not sustain the wheel contact pressures as well as the exterior portion of the section. (See Fig. 1.)

When a decided pipe in the ingot did not occur in cooling, the repeated pressures of the wheel contacts develop a check which is equivalent to a pipe, the metal immediately over it in the bearing surface stretching sidewise by its linear elasticity, the check widens until a portion of the head becomes detached from the web of the rail, unless removed from the track. (See Fig. 2.) The steel in the head is not homogeneous, either in quality or structure, and becomes distorted as a section, from inadequate physical properties of cubic or elasticity of volume, to sustain and distribute the wheel loads.

*Acknowledgment is made to the *Iron Trade Review* for the cuts used in this paper.—ED.

The splitting of the head in the earlier steel rails was in nearly all cases traced directly to a pipe in the ingot. These conditions still exist, yet there are numerous instances in which the pipe did not develop in cooling, but does in service, in the unsound metal of the central core of steel, as indicated in Figs. 1 and 2. Pieces break from the side of the head, in steel where so decided liquation

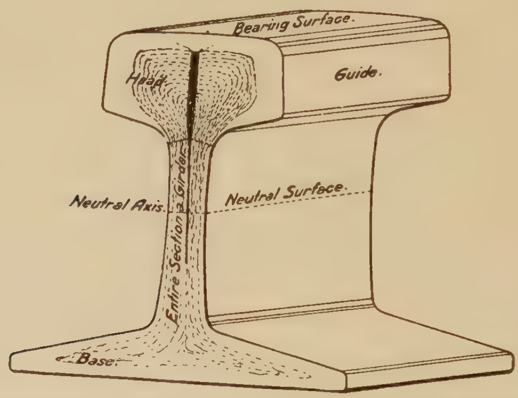


FIG. 1.—Section from Upper Portion of Ingot Showing Central Core and Pipe.

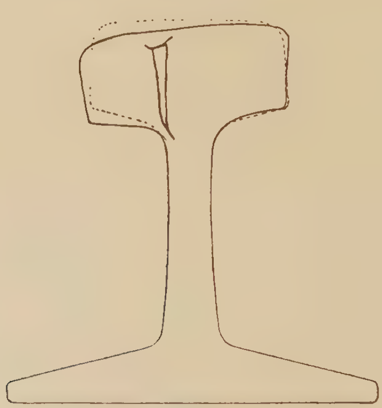


FIG. 2.—Check Developed in Rail-head by Service, 12 Feet in Length, Sound at Ends.

has occurred in the ingot as to make two or more grades of steel in the head.

The changed relations of the steel are not appreciated in the bearing surface to the wheel-contact pressures in the stiff sections, as the efficient engineering structures which have empowered the present wheel and total loads of the locomotives and cars. By the design of the section for a given weight, its mechanical properties have been increased, to transport heavier loads. To complete it as an engineering structure, with the requisite efficiency, the physical properties must also be augmented, in sound metal, to raise the limits of its cubic elasticity in the bearing surface proportionately to those required by its enlarged mechanical properties as an engineering structure. This is a problem of mechanics involving a metallurgical solution.

Iron rails failed in the bearing surface when the wheel loads increased to 10,000 pounds owing to the low limits of cubic or elasticity of volume of the metal. The two or three per cent. of slag made it a bundle of fibers only for the wheel pressures, though adequate to distribute the loads as a girder. Increase in stiffness in the iron rails to carry larger bending moments hastened their destruction.

The limber steel rails first rolled, the grain or texture of the metal was fine and compact. The elastic limits in reference to its cubic elasticity were high, and could sustain the wheel contact pressures without distortion. The conversion of the steel was less rapid, the ingots smaller, and liquation was slight. The present conversion, in larger vessels, teemed in larger ingots, are not as sound, for the entire length, as the smaller ingots. The tendency of the upper portion to form a pipe or become porous, or from the longer time in cooling, allows the metalloids to separate from the bath and become concentrated in an upper central core of the ingot. This does not produce homogeneous metal in the head. It is not capable of sustaining the wheel contact pressures by its cubic elasticity, and fails rapidly in service.

These are important problems in the manufacture of rails for the present traffic. It is not alone a question of heat treatment, a necessary, yet an over-estimated panacea for defective steel, but to secure a sound ingot, so that the metal in the entire head will be homogeneous.

The steel in the rail section should be sound and have sufficient physical properties and rigidity of structure to preserve the

shape of the section under the traffic, except the loss by wear of the wheel treads in the bearing surface, and the wheel flanges on the side of the head. Sound metal of 56,000 or more granulations per square inch, and elastic limits of 56,000 to 60,000 pounds, has sustained the present wheel loads without distortion of the heads. The facing ends of the rails should not flatten in sections having moments of inertia of more than 25 4th power inches. More limber sections are not fished sufficiently secure to prevent the wear of the facing ends of the rails under the shocks of the present wheel loads.

I have under observation rails made at several different mills and in those without effort to control or check liquation, the splitting and the piping of the rail heads is pronounced. In rails rolled from metal where attention was paid to checking liquation, the piping and splitting of the rail heads is practically unknown. The problems of checking liquation in large ingots are not always easy of solution, and must be solved in reference to the practice of each mill.

The metal for the stiff rails, the efficient engineering structures, must be sound, for any section to stand in the track without distortion under the traffic. If the steel contains a central core of harder material than the outside, or is porous, containing occluded gases, then it does not have sufficient toughness and tenacity of structure for the requisite limits of cubic elasticity to sustain the wheel load effects without distortion, and fails mechanically as an engineering structure.

INFLUENCE OF METHODS OF PILING STAYBOLT IRON ON VIBRATORY TESTS.

By H. V. Wille.

Staybolt iron, more than any other material, has been sold upon the reputation which certain brands have established rather than any upon particular physical properties. The reason for this is not far to seek for the life of a staybolt is so largely dependent upon conditions other than the quality of the iron, that it is hard to trace by service tests the effect of the quality of the iron upon the life of the bolt.

It is obviously impossible by such a test to determine the value of the material until after it has been used, and it can then only demonstrate that a particular brand of iron gives the best results at the time and under the specific conditions of the test.

It is a well-known fact that staybolts fail because of fatigue from the bending stresses induced by the expansion and contraction of the firebox. It would, therefore, appear to be logical to apply some fatigue test to material to be employed for this class of work, particularly since there is very little variation in the tensile strength, elongation and reduction of area of all good grades of iron universally employed for staybolts.

A large number of such tests have been made on the various brands of staybolt iron and, while there is sometimes considerable variation between the tests of two samples from the same bar of iron, the results conclusively show that the manner of piling exerts a profound influence upon the number of vibrations which a bolt will withstand.

Staybolts fail from fatigue and always close to the outside sheet. The fracture is in detail, starting from the base of a thread and gradually extending inwardly. The remedy lies in the employment of material of a sufficiently high elastic limit to prevent such a fracture from starting, and the use of a high steel naturally suggests itself. Such material has, however, found little favor

with users of this class of material because it is not adapted to a class of service in which stresses are localized at the base of a sharp thread, and because it does not permit of being readily hammered cold, for after staybolts are screwed into a sheet they must necessarily be headed in this manner.

For these reasons iron is almost universally used for the manufacture of staybolts, and it is obvious that an iron piled and worked with a view of breaking up the extension of a fracture, once started, should give the best results. Reasoning along these lines, a num-

TABLE I.

RESULTS OF VIBRATORY TESTS OF STAYBOLT IRON.

4,000 pounds load at 3-32″ deflection.

Code No.	Diameter.		No. of Revolutions before Fracture					Tensile Strength lbs. per sq. in.	Elongation, Per cent.
	Bar.	Nick.	Tests.	Average.	Max.	Min.	Range.		
40	1″	7/8″	6	3,961	4,547	3,137	1,410	49,960	29.25
345	1″	7/8″	6	3,212	4,709	1,479	3,230	50,300	30.75
348	1″*	7/8″	6	3,049	3,326	2,613	713	52,300	32.75
342	1″	7/8″	6	2,509	2,824	2,092	732	49,420	29.25
335	1″	7/8″	6	1,779	2,465	1,236	1,229	53,000	29.
343	1″	7/8″	9	1,774	2,784	1,076	1,608	48,400	28.25
346†	1″	7/8″	2	1,729	1,736	1,722	14	42,400	35.50
347	1″	7/8″	10	1,576	2,676	891	1,695	48,300	27.25
337	1″	7/8″	8	1,484	1,643	1,402	241	48,300	33.75
336	1″	7/8″	7	1,449	1,702	842	860	50,300	31.50
336	1″	7/8″	6	1,403	1,841	1,106	735	50,300	31.50
339‡	1″	7/8″	6	1,292	1,623	1,065	558	54,300	33.
338	1″	7/8″	6	1,263	1,443	986	457	49,800	28.25
343	1 1/8″	1″	6	2,206	3,420	914	2,506	48,400	28.25
347	1 1/8″	1″	9	1,442	2,131	1,036	1,095	48,300	27.25
344	1 1/8″	1″	6	1,145	1,430	932	498	49,700	28.75
347	7/8″	3/4″	10	685	1,316	327	989	48,300	27.25
341	7/8″	3/4″	6	561	896	439	457	50,100	25.00

* Scant inch. †Copper. ‡Steel.

ber of manufacturers were induced to pile an iron with a central core of small square piles and with covering plates on each of the four sides. The covering plates ensured a good sound thread and prevented the origination of a fracture due to bending the bolts at right angles to the fibers. The large number of central bars is designed to prevent the continuation of the fracture after it once starts.

These irons were subjected to the usual tests, and showed no difference from the results obtained from tests of standard makes of staybolt iron. The last two columns in Table I show that there

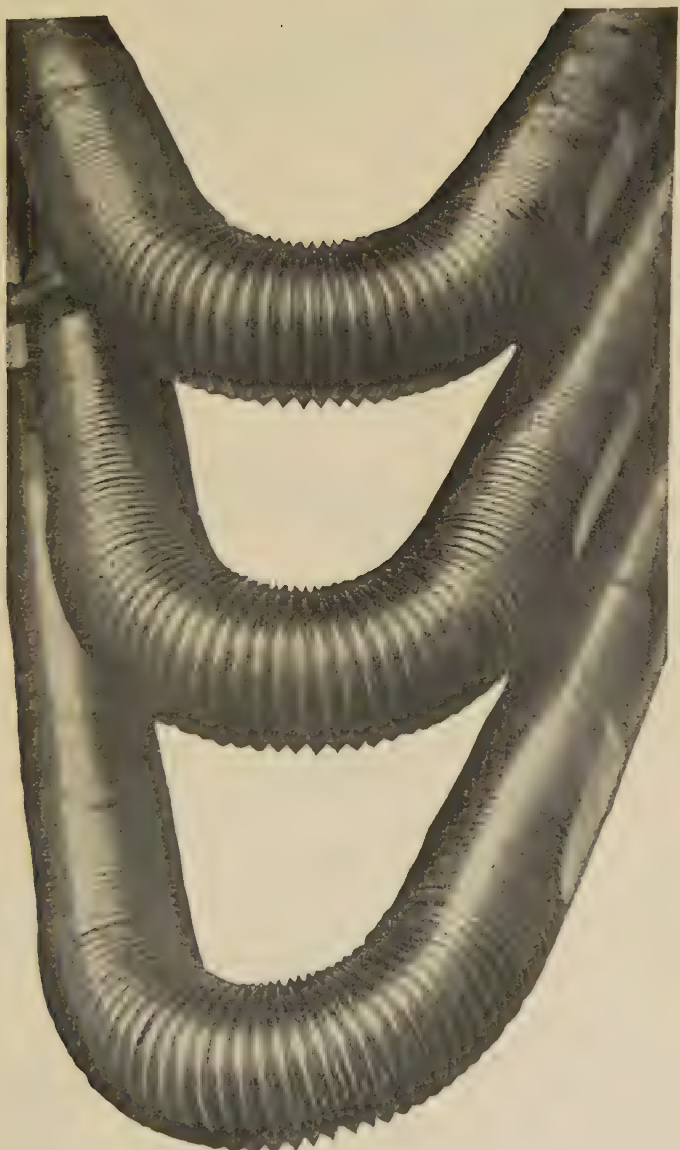


PLATE II.
PROC. AM. SOC. TEST. MATS.
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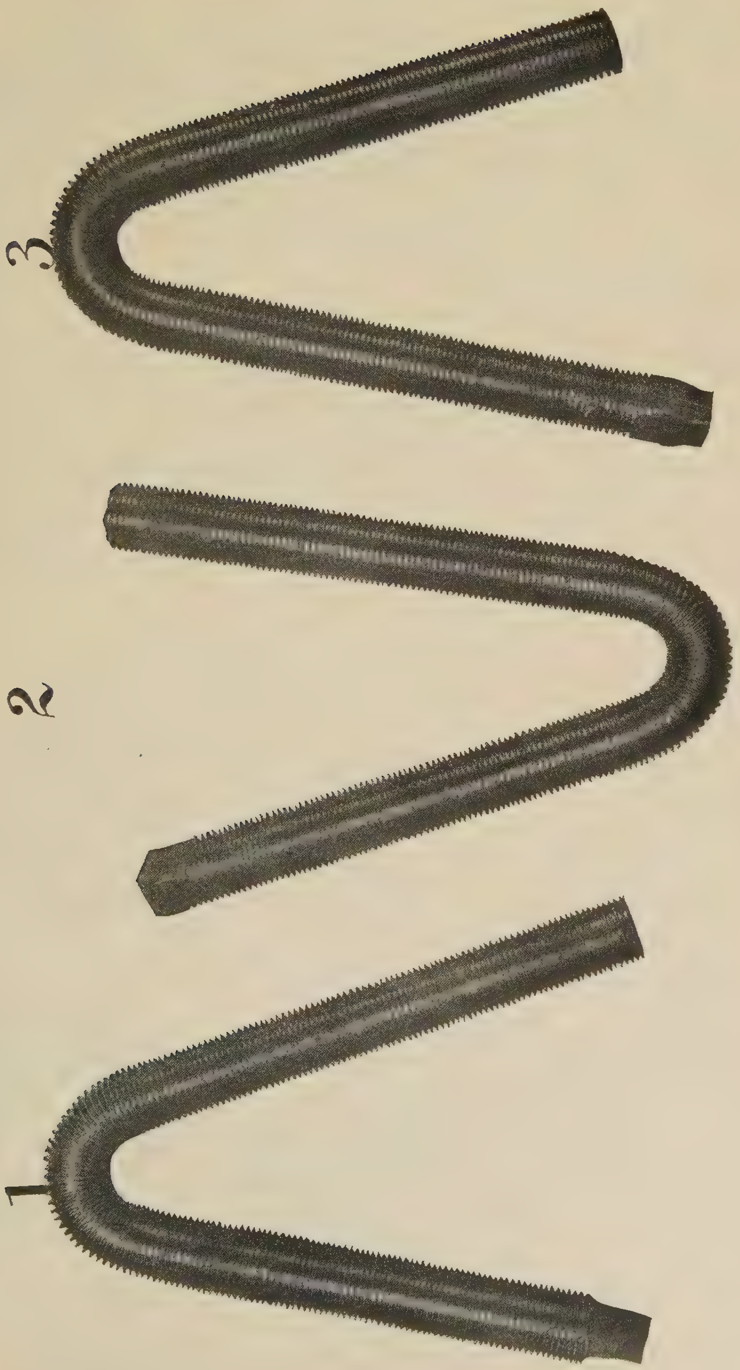
WILLE ON TESTS OF STAYBOLT IRON.



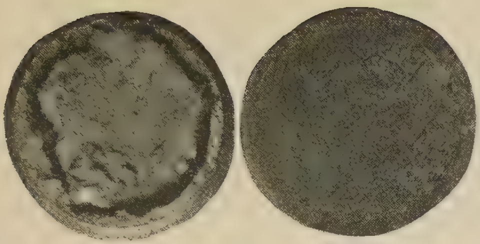


FIG. 1.

Vibrations, 3,961.
Tens. Str., 49.960 lbs.
Elongation, 29.25%.
Bar piled with 36 fill'g. pcs. 1" x 1".

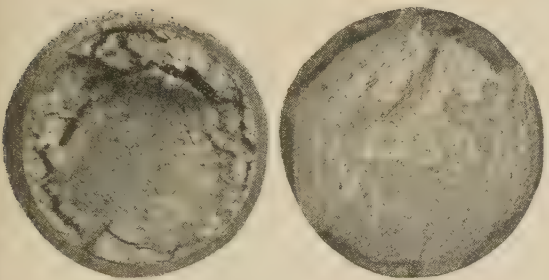


FIG. 2.

Vibrations, 3,212.
Tens. Str., 50,300 lbs.
Elongation, 30.75%.
Bar piled 10¼" x 10¼" with 36, 1" x 1" fill'g pcs.

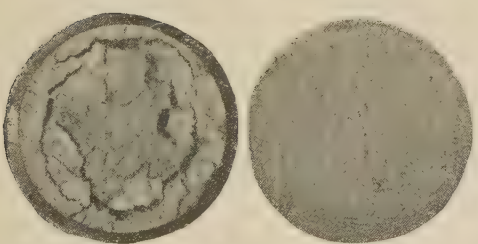


FIG 3.

Vibrations, 3,049.
Tens. Str., 52,300 lbs.
Elongation, 32,75%.
Bar piling with small fagots for filling.

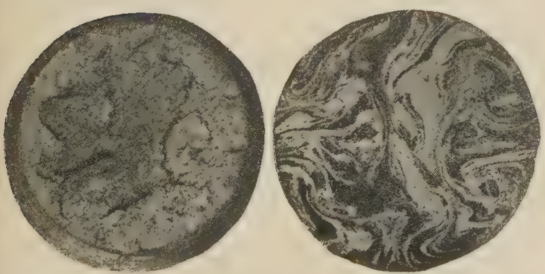
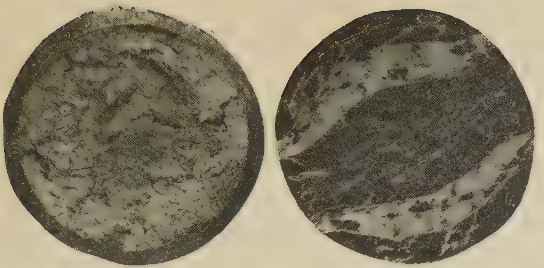


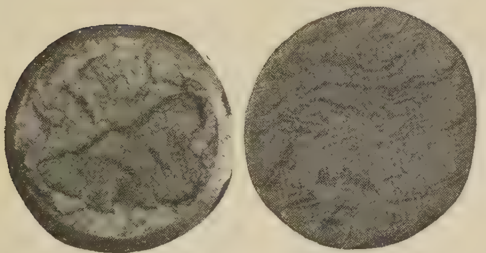
FIG. 4.

Vibrations, 1,403.
Tens. Str., 50,300 lbs.
Elongation, 31.5%.
Bloom Iron.



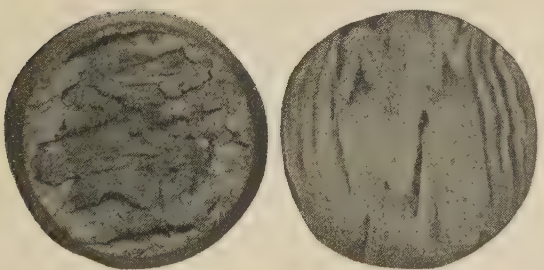
Vibrations, 1,263.
Tens. Str., 49,800 lbs.
Elongation, 28.25%.
Bloom Iron.

FIG. 5.



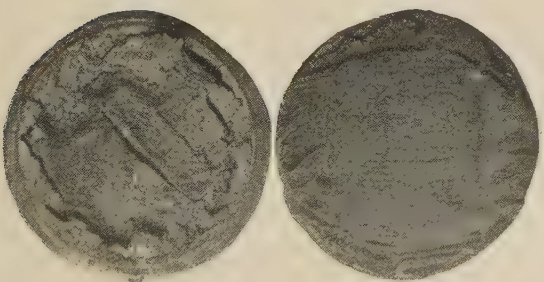
Vibrations, 1,484.
Tens. Str., 48,300 lbs.
Elongation, 33.75%.
Bloom Iron.

FIG. 6.



Vibrations, 2,509.
Tens. Str., 49,420 lbs.
Elongation, 29.25%.
Bloom Iron.

FIG. 7.



Vibrations, 1,576.
Tens. Str., 48,300 lbs.
Elongation, 27.25%.
Bar piling with flat bar filling.

FIG. 8.

is very little difference in the tensile strength of elongation of the various kinds of iron tested, the tensile strength varying but a few thousand pounds and the elongation but a few per cent. It is obviously impossible from an inspection of this table, to select the iron of which it can be asserted positively that it will give the best service for use as staybolts.

The irons were also subjected to the usual bending tests both on plain and threaded sections. Some tests on threaded bars are

TABLE II.

RESULTS OF VIBRATORY TESTS OF VARIOUS MAKES OF STAYBOLT IRON.

Six pieces off the same bar with 4,000 lbs. load at different deflections.

Code No.	Diameter.		No. of Revolutions before Fracture.			Revolutions before fracture in per cent. of the revolutions required to fracture with a deflection of 3-32 inch.		
			Deflection.					
	Bar.	Nick.	1/8″	3-32″	1-16″	1-8″	3-32″	1-16″
346*	1″	7/8″	475	1,719	8,185	27.8	100.	479.
340	1″	7/8″	1,395	3,860	23,146	36.1	100.	599.
343	1″	7/8″	1,040	3,293	12,931	31.6	100.	392.
345	1″	7/8″	828	2,648	21,364	31.3	100.	769.
348	1″*	7/8″ †	1,280	2,606	8,340	59.1	100.	320.
347	1″	7/8″	468	2,314	10,152	20.2	100.	438.
335	1″	7/8″	736	2,206	16,145	33.0	100.	731.
342	1″	7/8″	1,104	2,195	3,015	52.7	100.	144.
336	1″	7/8″	794	1,711	4,791	46.4	100.	280.
337	1″	7/8″	....	1,433	6,140	....	100.	428.
338	1″	7/8″	420	1,206	8,112	42.0	100.	674.
339‡	1″	7/8″	701	1,167	3,959	60.1	100.	340.
347	1 1/8″	1″	945	2,344	9,118	40.2	100.	388.
344	1 1/8″	1″	614	1,583	7,467	38.7	100.	471.
347	7/8″	3/4″	338	1,016	4,070	33.3	100.	402.
341	7/8″	3/4″	287	361	2,430	79.5	100.	673.

*Copper. †Scant inch. ‡Steel.

shown in Plates I and II. When these are properly made they likewise show little variation.

When, however, the irons are subjected to the vibratory test, they show marked differences, and they separate themselves into groups dependent upon the method of manufacture.

Figures 1 to 8, Plates III and IV show (1) samples broken under the vibratory test, and (2) etchings to show the piling and method of manufacture. These irons are representative of those tested, and the correlation of the results of vibratory tests and method of manufacture is apparent from a study of Plates III and IV.

It will be noted that the iron runs in groups:

1. Those irons which have been rolled from sufficiently large piles and having covering plates with a central core composed of from 25 to 36 small square bars. These irons from various manufacturers give from 3,000 to 4,000 double vibration.
2. The various kinds of blooms are hammered iron, giving from 1,000 to 2,000 vibrations.

FIG. 9.

3. Bar-piled iron with flat bars as filling pieces giving about the same number of vibrations as shown by group 2.

If any value can be placed upon the vibratory tests, these results conclusively show the advantage of the method of piling illustrated by the irons in group 1.

The tests also show that when an iron is well worked and possesses good long, strong fibers, that the fibers split longitudinally

after extending across the face of the specimen. Irons showing these characteristics gave good results even though not piled in the most approved manner. A characteristic failure of this kind is shown in Fig. 9.

These tests were all made upon a nicked-in place of a threaded specimen, it being deemed that nicking would eliminate the variable introduced by the use of dies. The tests were made under 1-8″, 3-32″ and 1-16″ deflections, as shown in Table II, but 3-32″ deflection was selected as giving the most representative results.

While the various bending tests have met with a good deal of favor, and are to-day among the best in general use, there is a demand for a more definite test and one which will at once show the characteristics of the various grades of iron. The vibratory test would appear to be the most promising method of testing material of this nature, and while there are many points still to be determined, it undoubtedly possesses merit.

DISCUSSION.

Mr. Wickhorst.

MR. MAX. H. WICKHORST.—Such tests as I have made indicate likewise that piled iron will stand more vibrations than bloom iron. It is a question though, whether if both materials were subjected to the right kind of heat treatment, that difference would actually exist in the finished material. In other words, it is just possible that one material may have been finished at a much lower temperature, although in that case we ought to be able to discover the difference in the reduction of area.

Mr. Kinkead.

MR. J. A. KINKEAD.—I put in a vibration-test machine some time ago, reducing all the variables I possibly could. I found that I could not duplicate results sometimes within 200 per cent. I noticed the same thing in the experience of others on material I furnished. Some would get very good, others very poor results. The iron was as nearly the same as it was possible to get it. I have taken five bars, and made five tests on each, getting 200 to 800 vibrations on pieces from the same bar. I think, therefore, that the matter of vibration tests should be taken up very thoroughly and check tests made on the same bar, or other means adopted to find out whether we can duplicate results within satisfactory limits, of, say, a few per cent. On the tensile strength we can get check results within very small limits. Until we can devise a machine that will give results on check tests within satisfactory limits, I think it would not be well to adopt a vibration requirement. Otherwise every testing engineer will have a vibratory-test machine of his own, the design of which he thinks better than any other. The result will be that anybody proposing to sell iron to a railroad company who wants to know how the material will test will have to have a machine of each kind, and may require twenty different machines. At present I think there are about five. The results from one machine do not compare at all closely with the results from any other.

Mr. Wickhorst.

MR. WICKHORST.—For the purposes of investigation an elaborate vibratory machine may be required, but for simple

inspection purposes a machine can be devised almost anywhere, and, as I look at it, it is one of the functions of our Committee M to recommend some standard, simple method of making vibratory tests. **Mr. Wickhorst.**

As regards variations in results, some ten or twelve years ago the Burlington Road made quite a series of vibration tests, and the first tests were made by simply screwing the staybolt into a plate and hammering over the end to simulate service conditions. We then made special clamps to hold the staybolt ends, and even under these conditions there was a certain amount of play and the axis of the bolt where clamped was moved through a small angle. In order to overcome or minimize that we simply put an extension on the bolt so as to hold it at two places, six inches between the clamps, and, in that way, even if the clamps were not perfectly tight, still the axis of the bolt could not move very materially at the place where the bolt was held. With this it was possible to get somewhat more consistent results, but even then there was considerable variation. I think these variations are due mostly to variations in the material, which, perhaps, are local, but nevertheless represent actual variations in the material.

MR. KINKEAD.—In my vibration tests I eliminated all variables as far as possible. I used 6-in. lengths, and held the bar between tool steel dies. The dies were held by four bolts set by means of a long wrench and spring balance as recommended by the Baltimore and Ohio Railroad Company. To give an even stress on the bolts, the back bolts were set, while the stress was off. The pieces were then reversed, and the front bolts set. The pieces were cut by the same die and all taken from the same bar of iron. The iron used did not show an average of more than 1.5 per cent. elongation, nor more than 300 or 400 lbs. in tensile strength. Even with iron of such uniform character, results varied from 200 to 800 vibrations. **Mr. Kinkead.**

One more point. Under service conditions the vibratioen in the boiler will not produce stresses in staybolts exceeding ths elastic limit of the metal. Iron can not be stressed beyond the elastic limit without injury. With the vibratory test-machine the stresses exceed the elastic limit.

MR. WICKHORST.—Mr. Kinkaid states that in service the staybolt can not be bent beyond the elastic limit. I think he is **Mr. Wickhorst.**

Mr. Wickhorst. much mistaken. In the ordinary process of firing up a locomotive boiler, starting with cold water, the water at the crown sheet is heated first, and I have found by actual tests a difference of temperature of as much as 200° F. during the process of firing up. Again, during the process of injecting cold water into the boiler with the ordinary check-valve, the cold water flows in underneath the water already in the boiler causing a drop of, perhaps, 100° F. at the mud ring. Keeping these facts in mind, we can readily imagine movements of the staybolts amounting at times to $\frac{1}{8}$ to $\frac{1}{4}$ in. in some places.

Mr. Wille. MR. WILLE.—The vibratory tests are as specific as the drop tests, but they have hitherto been made in a crude way. The chief difficulty has been the difficulty of getting a very tight clamp so that the bolt does not vibrate in the clamp. Inasmuch as bolts are vibrated in service through a definite angle, it has been customary to make the vibratory test by specifying a vibration through a definite angle in place of specifying that they should be vibrated under a given fiber stress in flexure. This corresponds with specifying a drop test without limiting the maximum deflection. Some irons may require a load of 3,000 lbs. to deflect $\frac{1}{8}$ in., while others may require 6,000 lbs. The latter will be subjected to a higher fiber stress than the former for a given deflection.

One curious thing about the vibratory test of staybolts is, that iron that shows a maximum vibration at a small deflection shows a minimum vibration at a large deflection; and, vice versa, iron that shows a large number of vibrations at a large deflection shows a small number at a small deflection. This points to the fact that it will be necessary to specify the fiber stress and the amount to which the bolt should be strained in bending. If this be done, the results will be concordant, and even more definite than many of the bending, drop tests or impact tests.

A PRELIMINARY REPORT ON THE EFFECT OF COMBINED STRESSES ON THE ELASTIC PROPERTIES OF STEEL.

By Edward L. Hancock.

For some time engineers and others have been interested in the effect of combined stresses on the materials of construction. Lord Kelvin in the preparation of his article on Elasticity for the Encyclopedia Britannica, had a series of tests made on piano wire. The wire having sufficient weight to hold it straight while suspended was subjected to a torque at the bottom; when an additional weight was added it was found that the elastic limit of the wire in torsion was lowered. From these tests it seemed possible that the same thing would be true in the case of compression-torsion (loaded columns), although no tests of this kind were made.

Mr. J. J. Guest, in England (see Proc. Physical Soc. of London, Sept., 1900), carried out a series of tests to obtain the effect of combined stresses on ductile materials, the materials used in the tests being wrought iron, mild steel, copper and brass. The results of these tests also lead to the same conclusion, that the elastic properties are lowered when the materials are subjected to combined stresses.

The slight knowledge on this subject and the entire absence of any information available for engineers have inspired the writer to carry out a series of investigations that should give some information immediately available for practical work. The series contemplated includes the following:

(*a*) Tests of steel and iron solid rounds and hollow tubes in tension while under torsion.

(*b*) Tests of steel and iron solid rounds and hollow tubes in torsion while under tension.

(*c*) Tests of steel and iron solid rounds and hollow tubes with increasing tension and torsion.

(*d*) Tests of steel and iron solid rounds and hollow tubes in compression while under torsion.

Thus far only a part of series (*a*) on solid steel rounds has been carried out and the results given in this report are taken from these tests.

Apparatus for Testing.—The difficulty of making tests of materials under combined stresses lies, principally, in the fact that no machines are available for such tests. The apparatus used in the tests under consideration is shown in Fig. 1.* It consists

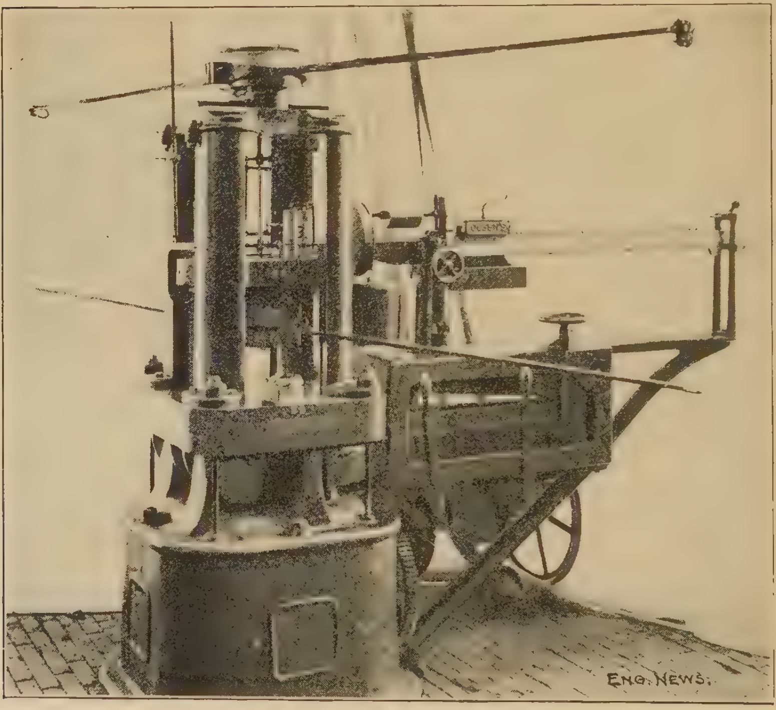


FIG. 1.

of two specially constructed *heads* fitted to an ordinary 100,000-pound tension testing machine. Each of these heads consists of a flat cast iron base fitting into the slot in the head of the testing machine provided for the insertion of the wedges, as ordinarily used. The outer side of this casting is finshed to provide for three

* Acknowledgment is made to the *Engineering News* for the cuts used in this paper.

concentric rows of hardened steel balls, which rest upon a steel plate and are covered by another steel plate. The outer side of this latter plate is a spherical cup. This receives the large casting, or chuck, carrying the wedges and arms. The spherical bearing allows the specimen to "line up" properly. The construction of the heads is seen in Fig. 2. Each head is provided with two arms

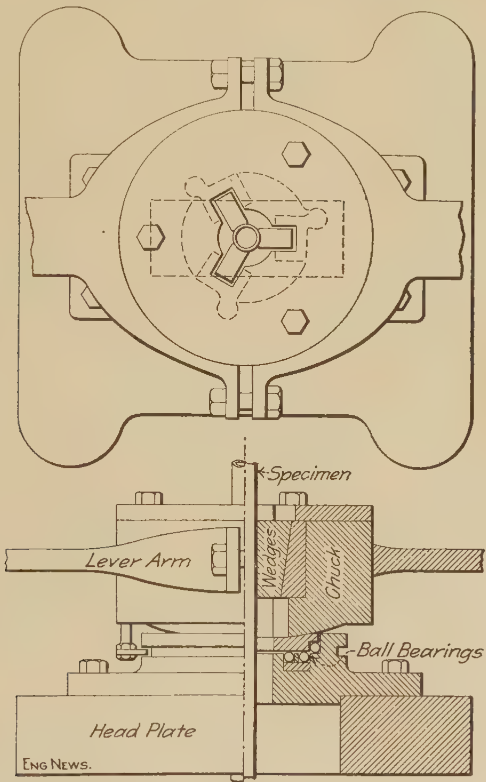


FIG. 2.

5 feet long, the lower arms having steel rollers that bear against stationary knife-edges, and the upper arms are provided with knife-edges and stirrups to which the cords carrying the loads are attached.

In order that the loads in torsion might be applied, two frames were constructed to support the stationary knife-edges for

the lower arms and also to carry bicycle wheels over which passed the cords that were attached to the upper arms. These wheels were so located that the cord was perpendicular to the arm and on the same horizontal. To the other end of the cord was suspended a small bucket as a receptacle for the sand used in loading. The buckets were counterbalanced by a weight attached to a cord running back over the wheel.

Method of Holding the Specimen.—The large casting of each head carries three lugs provided with slots for the insertion of the wedges. These lugs are so arranged that when a torsion load is applied the wedges tend to *grip* the specimen, due to the swinging out of the lugs, see fig. 2. This method of holding allows the use of specimens of different diameter and admits of easy manipulation.

Application of Load in Torsion.—The desired load in torsion was given by allowing a known quantity of fine dry sand to run uniformly into the buckets attached to the cords. This load was transmitted to the arms and a part of it to the specimen (a part was taken up by the friction of the bearings). The use of sand gave a uniform application of load and was very satisfactory.

Measurement of Twist and Elongation.—The amount of twist was measured by means of an ordinary troptometer on a 10-inch gauge length, and the elongations were measured by a Yale-Riehle extensometer on an 8-inch gauge length. The extensometer was placed symmetrically between the arms of the troptometer. This means of measuring deformations was entirely satisfactory for the series of tests made but will have to be changed somewhat for the series (*c*).

General Method of Testing.—The tests of series (*a*) already made consist of two sub-series (E) and (C); the former on 3 per cent. nickel steel and the latter on carbon steel, both being supplied through the courtesy of the Carnegie Steel Co. The metals used had the following composition:

	Phos.	Mn.	Silicon.	Nickel.	Carbon.
Nickel steel..........	.019	.65	.022	3.02	.25
Carbon steel	.030	.55	.024	0.00	.24

In each series three pieces were used. These were about 3 feet long and .85 inches in diameter and turned down for a length of 11 inches at the center to a diameter of .50 inches. In each case

a tension load of 4,000 lbs. per sq. inch was applied to hold the specimen in place and cause the wedges to grip properly. One specimen in each series (E_A) and (C_A) was tested in torsion to $\frac{1}{3}$ the elastic limit by application of sand, troptometer readings being taken. The specimen, while held with this load in torsion, was tested in tension to the elastic limit. A second specimen in each series, (E_B) and (C_B), was tested in torsion in the same way to $\frac{2}{3}$ the elastic limit and while under this load in torsion was tested in tension to the elastic limit. The third specimen of each series

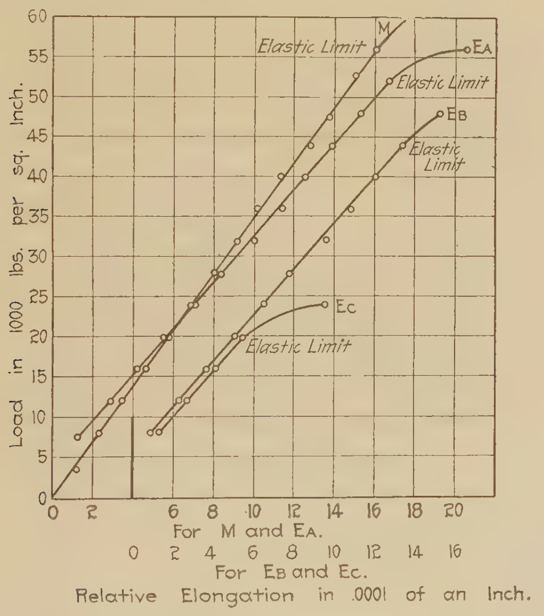


FIG. 3.

(E_C) and (C_C) was tested in torsion to the elastic limit and, while under this load, was tested in tension to the elastic limit.

Friction of the Heads and Rollers.—The friction of the rollers attached to the lower arms and bearing on the stationary knife-edges was measured and found to be negligible. That is, the amount of upward pressure due to this friction (constant for these tests) was less than could be read on the beam of the 100,000-lb. Olsen testing machine.

The effective moment due to the friction of the ball-bearings and bicycle wheels was determined for the tension load of 800 pounds (corresponding to a load of 4,000 lbs. per sq. inch), this being the constant load in tension used while the torsion tests were being made. The tests were made by placing the heads on the platform of the machine, back to back, and compressing them with a load of 800 pounds and determining the weight of sand necessary to move the arms. The average of a number of tests gave 16.42 inch-pounds as the effective twisting moment due to the friction

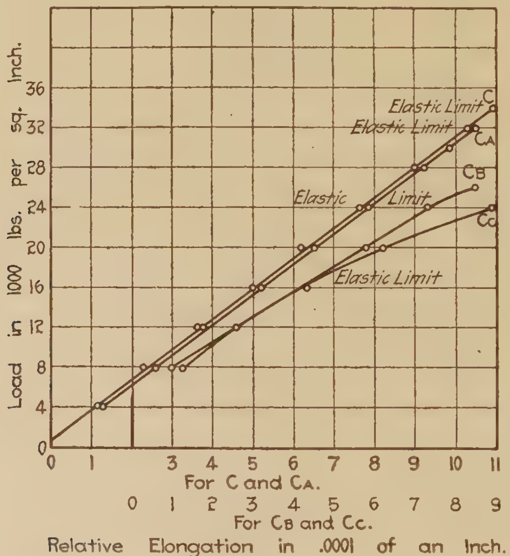


FIG. 4.

of the heads and bicycle wheels. This moment was deduced in making calculations.

It is seen from the above that the effect of friction in the tests already made has been accounted for in a definite way, making the tests satisfactory. The plan of work includes the determination of a *friction curve* for the apparatus. This curve will show the twisting moment lost due to friction for any safe load in tension.

Results of Tests.—Fig. 3 gives a stress-strain diagram of nickel steel in tension. The curve (M), is a curve from the average

of two simple tension tests of the material and shows the elastic limit to be 56,000 pounds per sq. inch. The curves (E) represent the behavior of the mtaerial in tension while held in torsion; (E_A), held in torsion at $\frac{1}{3}$ the elastic limit, (E_B), held in torsion at $\frac{2}{3}$ the elastic limit, and (E_C), held in torsion at the elastic limit. The curves show a lowering of the elastic limit in tension; a lowering of about 7 per cent. in the case of (E_A), about 21 per cent. in the case of (E_B), and about 63 per cent. in the case of (E_C). When the series of tests contemplated has been completed, it is hoped that the law of the lowering of the elastic limit may be determined. The modulus of elasticity in tension has also been lowered.

Fig. 4 shows the stress-strain diagram of carbon steel in tension. The curve (C), the average of two simple tension tests of the material, shows an elastic limit of 34,000 pounds per sq. inch. The curve (C_A) shows the result of a tension test, made while the specimen was held at $\frac{1}{3}$ its elastic limit in torsion; (C_B), while held in torsion at $\frac{2}{3}$ its elastic limit; and (C_C), while held in torsion at its elastic limit. These curves also show a lowering of the elastic limit, a lowering of about 6 per cent., 30 per cent. and 54 per cent. for (C_A), (C_B) and (C_C), respectively. It will be noticed that this is not exactly the same *rate* of lowering as that given by plate (1). The modulus of elasticity in this case does not seem changed in the case of (C_A), but is lowered considerably in the case of (C_B) and (C_C).

In all cases the increase in the troptometer readings while the loads in tension were being applied—and this, notwithstanding the increased friction of the heads—showed a decided weakening of the material due to the combined stresses. However, sufficient data have not been taken to give a satisfactory report on this point.

Fig. 5 shows two torsion curves (A) and (B), the former represents an average of two tests of the material made while the specimen was under a tensile load of 4,000 pounds per sq. inch, and the latter represents an average of two simple torsion tests of the same material. The curves show the expected lower elastic limit in the case of the specimens subjected to combined stresses. In the case of this plate the ordinates represent the shearing stress on the outer fiber and the abscissæ the angle of twist measured at the center of the specimen.

When the tests have been more completely worked out it is planned to compare the values obtained from the tests under combined stresses with those obtained by computing the formulæ:

$$q_s = \tfrac{1}{2}\,[p^2 + 4p_s^2]^{\frac{1}{2}}$$
$$q = \tfrac{1}{2}\,(p + [p^2 + 4p_s^2]^{\frac{1}{2}})$$

Where p is the load in pounds per sq. inch in simple tension, p_s the

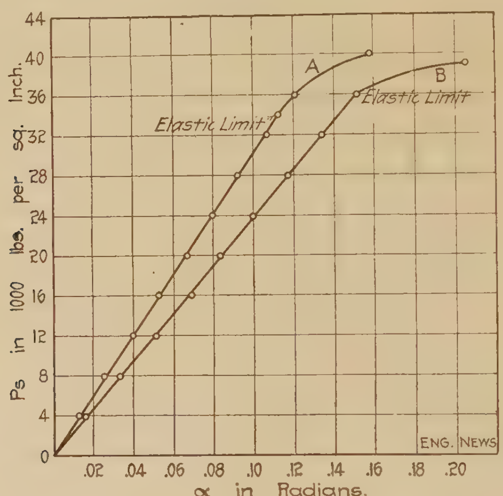


FIG. 5.

shear on the outer fiber in simple torsion and q and q_s the normal and shearing stresses on an internal plane of the material.

In conclusion, the writer wishes to acknowledge the efficient work of several senior students who made it possible to carry out the tests that have been made: Mr. Carlos Robles Gil, Mr. C. E. Shearer, Mr. F. O. Blair, Mr. W. R. Wheeler, Mr. J. H. Lambert and Mr. J. W. Krull. And to acknowledge particularly the helpful suggestions of Professor W. K. Hatt in charge of the Laboratory for Testing Materials.

DISCUSSION.

The President.—Perhaps it may throw a little light on the question of composite stresses, to consider for a moment the locomotive driving wheel tire. In this structure we have first, the stress, due to setting the tire. Some of us have been astonished, in attempting to find out what this stress is, at its possible magnitude. Nobody knows positively we think, but there are indications that the stress in the metal due to the setting of the tire alone may be from 20,000 to 45,000 lbs. per sq. in. Again, the weight on the drivers produces a compressive stress at the point of contact with the rail. This stress has been at least doubled within the last twenty-five years, owing to the increase in the weight of locomotives. No one knows how much this stress is, because the positive area of contact is indeterminate. Again, the action of the steam in the cylinder to produce tractive effect, introduces a stress at the point of contact of the tire with the rail, which, likewise, has more than doubled within the last twenty-five years. In addition, the tire is, of course, subject to stresses from shocks and blows, due to irregularities in the track and to the swaying of the engine. It may be interesting to state that the increases mentioned above are seriously bringing up the question in modern locomotive construction, as to the limit that tires can be worn down, before they are too weak to successfully withstand these composite stresses. **The President.**

Mr. H. H. Campbell.—As I understand the tests described in the paper, the direct torsional load was applied stressing the metal up to the elastic limit, and then a determination was made of the tensile elastic limit, and there was found to be a reduction of 63 per cent. Would it not follow that the reverse would be true and that under stress in the tensile line there would be a reduction of 63 per cent. in the torsional elastic limit? If so, why did not the metal give way in the torsional direction at the same time? If all this is true, then the strength of boilers must be recalculated because the longitudinal and circumferential stresses would reduce the elastic limit in both directions. **Mr. Campbell.**

Mr. W. K. Hatt.—It seems to me that the analogy between **Mr. Hatt.**

Mr. Hatt. a boiler subjected to stresses at right angles to each other and the case under discussion, where a bar is put under combined torsion and tension, is not close. Some of these bars were stressed in torsion to their elastic limit as determined by the previous torsional tests, and then subjected to an increasing tension. This process reduced the elastic limit in tension 63 per cent. The difficulty raised by Mr. Campbell will be less if he recalls that the torsional stresses in the bar decrease from the circumference towards the center and it is only the outside material of the bar that is subjected to the full torsional elastic limit stress.

Mr. Colby. MR. A. L. COLBY.—As Mr. Hancock, the author of this paper is absent, I prefer not to discuss in detail certain points in his paper. The Secretary gave me an opportunity of glancing over the paper yesterday as I expected it would be presented, according to the program, at yesterday afternoon's session.

I am glad to note that the author entitles his paper a "Preliminary Report," and states that until further tests have been completed by him that he will postpone making any suggestions for the improvement of the standard formula now used in calculating combined stresses.

Every structural engineer will agree with me that any change in this formula, in such general use, should not be suggested until a thorough set of tests of structural carbon steel and structural nickel steel are completed. So far, the author has only made three tests on two steels, one structural carbon steel of the usual carbon content, 0.20 to 0.25 per cent., and the other, structural nickel steel of similar carbon content, and containing about 3.00 per cent. of nickel. These two steels he tested at a torsional strain of one-third of their elastic limit, two-thirds of their elastic limit, and at the elastic limit. This, in my opinion, is the proper way to compare the two steels, as the true measure of their value is their elastic limit, although the ultimate strength is usually taken as a basis for the calculation of the so-called "factory of safety."

The point I wish to raise is that by the addition of nickel to structural steel, the carbon can be safely raised without any danger of brittleness, and further that the addition of nickel to steel increases the ratio between the elastic limit and the tensile strength. This has long been appreciated by engineers looking for a material to withstand severe service. The first important evidence of the

appreciation of the qualities of structural nickel steel was its adoption for the main eye-bars for the Blackwell's Island Bridge now in course of construction. The specifications call for the following physical requirements for the two structural steels: **Mr. Colby.**

Material.	Physical Properties.	Structural Nickel Steel.	Structural Carbon Steel.
Eye Bars (unannealed)	Ultimate Tensile Strength	100,000	66,000
	Elastic Limit ..	55,000	One-half of Ultimate.
	Elongation in 8″	$\frac{1,600,000}{\text{Ultimate Tensile Strength.}}$	$\frac{1,500,000}{\text{Ultimate Tensile Strength.}}$
Pins (unannealed)....	Ultimate Tensile Strength	90,000	66,000
	Elastic Limit ..	50,000	One-half of Ultimate.
	Elongation	20% in 2″	$\frac{1,500,000}{\text{Ultimate Tensile Strength}}$ in 8″

The speaker hopes to be in a position to present to the Society, at its next annual meeting, an elaborate set of tests on structural nickel steel of the proper carbon content when nickel is present and the standard structural carbon steel designation in the Standard Specifications of the Association of American Steel Manufacturers as "Medium Structural Steel" of a guaranteed ultimate strength of 60,000 to 70,000 pounds per square inch, and a required elastic limit of not less than one-half the tensile strength. Had he known that this paper was to be presented at this meeting he would have come prepared to make a preliminary report covering some of the points brought up by the author of this paper.

The speaker would like to take this opportunity of offering samples to any engineers desiring to make comparative tests of structural nickel steel and structural carbon steel.

In closing he would like to emphasize the statement made in opening his remarks, that any change in the present formula for combined stresses should not be made before comparative tests have been made on several samples of both steels with carbon between the limits of 0.20 to 0.40 per cent.

Mr. Hatt.

MR. HATT.—The material experimented with was supplied by the Carnegie Steel Company. This particular material is being experimented with under different forms of tests. This paper simply describes the starting point of the investigation, and the results are quoted as showing the methods and machines. There are no conclusions reached with regard to the relative value of nickel and carbon steel to withstand compound stress.

The President.

THE PRESIDENT.—Before this discussion is closed I should like to raise the question as to how much we know about the behavior of steel when it is subjected to stress in such a way that the metal cannot flow. For example, take the stress at the shoulder of a car axle. This is a transverse stress with apparently very little chance for the metal to flow. How does steel behave under such stresses? Again, take the cracking of the fire-box of a locomotive under washing. The middle portion of the sheet will sometimes rupture for a distance of 18 in., and, apparently, there is absolutely no flow. It may not be amiss for us to think about this problem as time progresses.

A COMPARISON OF STANDARD METHODS OF TESTING CAST IRON.

By Richard Moldenke.

In reviewing the situation as it exists to-day, we see that all the work carried through in connection with the testing of cast iron lies in the direction of standard specifications. The only nations which have accomplished something definite are Germany and the United States. The others are still working at the problem.

As pig iron is the basis of the foundry industry, our attention must be first directed to it, and we find two general specifications in use: the American ones, and lately a pig iron contract drawn up in England. In the American specifications we have the direct recommendation that all pig iron be purchased by analysis. Detailed instructions are given as to sampling, and also the course to be pursued in case of a disagreement on the analytical work. An important omission, and one which it will take time to supply, is the adoption of standard methods for analysis. Without these, even the best of specifications still leave a loop-hole for controversy. Incidentally, it may be said that the American organization of foundrymen is taking this matter up, and has already prepared a standard method for determining silicon in pig iron and cast iron. Total carbon is to follow, and then sulphur, phosphorus and manganese. As these methods are tested out in practice outside of the foundrymen's organization, we will learn their practical value for specification purposes better.

Continuing with the American pig iron specifications, we next come to the allowances and penalties. Here there is given the limit of difference allowable in the pig iron delivered from that specified, and the penalty that may be exacted where the limit is exceeded, and yet not be too great to absolutely reject the metal. These provisions enable foundries to purchase pig iron with the reasonable assurance that they get what they want nearly enough, without causing the slightest trouble in the shop routine. The

cash penalty further prevents the furnace from taking chances on shipments to people who watch their supplies carefully.

For the benefit of the trade in general, inasmuch as only the minority of foundries are equipped with laboratories, or have expert advice, there is given a table of base analyses of grades, so that if a purchaser pins the specifications to his order, and calls for, say, a Number 3 iron, he will get just what a Number 3 iron should be in composition, so far as the silicon and sulphur are concerned. When the use of chemistry in the foundry is so general, and the furnaces are run in such a way that one iron is as good as another, we may see these specifications extended to include the other elements. At present the phosphorus, manganese, and the carbons are questions of brand and locality largely, the furnace industry being quite settled in classes for pig iron distribution.

Germany has not yet seen fit to standardize pig irons, and reports from the other side indicate that conditions are not so favorable, the application of our American specifications being out of the question for German irons. A man calling for iron with the sulphur we give, and be it said that our sulphur limit is high, would have to pay fancy prices in Germany, for they are badly troubled with that element over there.

The same may be said of England, and on looking over the new pig iron contract issued by the London Metal Exchange, we find that while the sulphur allowed is not much larger than ours, yet he very much higher silicon that goes with it, practically makes a great difference. Thus while we have a Number 2 pig iron run 2.25 in silicon, with a variation of 10 per cent. either way, or 2.00 to 2.50, and this has a maximum of 0.045 sulphur allowed, the English standard, with the same sulphur, allows the silicon to vary from 2.50 to 3.50, which would correspond to our Number 1 with a higher sulphur. The English specifications also give rules for sampling, but lay much stress upon the brand names.

Incidentally, it may be mentioned that America is taking up the question of standardizing foundry coke, which is a step in advance, and will have a far-reaching influence not only in foundry practice but also on the blast-furnace.

To turn now to specifications for testing cast iron. In America we have adopted a set for pipe, locomotive cylinders, malleable castings; and there are pending those for castings in general and

for car wheels. Over here we take out from the general work, the special groups, which can stand by themselves and have properties peculiarly their own, which may be determined by specific tests. In Germany they have specifications for machinery castings, for columns (which we are trying to get away from as quickly as possible), and for pipe.

In dividing the classes of castings relative to their thickness, for this is an important point to consider when specifying breaking strength, we have adopted a little wider limit than the Germans. Thus we have small castings at ½ inch or less. They have 0.6 inch or less, or a little more. For medium castings, however, we have from ½ inch up to 2 inches, while the Germans have from 0.6 inch to 1 inch. For heavy castings we have 2 inches and over, while they have everything above 1 inch in that class. Either our conception of a heavy casting is different, or else German customs lay more stress on narrower limits for medium castings.

A further difference between the American and the German specifications may be found in the chemical end. We specify the upper limit for sulphur, so as to secure reasonable strength against shock. This is not looked after in the German specifications, possibly because of the difficulty in getting low sulphur irons for the foundry.

The point that interests us most, however, is the method by which a metal is judged. That is to say, the test-bar employed. Comparing the general specifications advanced for Germany with our own, now pending, we see that special pains are taken in both cases to get representative test-bars, and these are not to be cast on the piece. Herein there is a distinct advance, cutting off the old "coupon." The transverse test is prescribed, which agrees with our experience. The tensile test is omitted entirely in Germany, and it is to be hoped that we may follow suit some day also, as no good end is served when no two testing machines agree in the alignment and grip on the specimen.

We find a radical difference in the length of the bars used. Our own are comparatively short, and this has caused some comment on the other side, our German brethren concluding that we do not lay as much stress on the transverse test as we should. We, on the other hand, believe that with the long bars in use formerly, much of the sensitiveness of the transverse test is lost, for even

poor iron will show good results, if the test is carried out slowly and carefully. On the other hand, with a comparatively quick test on short bars, the iron must be of good quality to show a good deflection and strength.

Three bars are provided by the Germans. For small castings the diameter is 0.8 inch and the distance between supports 16 inches. For the medium castings the figures are 1.2 inch diameter and 24 inches between supports. For the heavy castings the diameter is 1.6 inch and the testing distance 32 inches.

It will be noted that the German aim is to get as near the size of the casting to be represented as possible, and this is to be commended in a way. However, we realize over here, that the lack of homogeneity in the structure of cast iron is such an element in the problem that the records of several sized bars are not mathematically comparable, as would be the case in steel. Hence, we would not feel safe to accept the result of a long and thick bar as compared with a shorter and thinner one, in order to judge whether the iron in one is better than in the other.

While realizing that it is desirable to vary the diameter of the bars, but not the length, we reluctantly confined ourselves to one bar for all purposes, aiming only to get the actual quality of the metal with given standard conditions, identical for each heat, so far as foundry practice can accomplish this. We can, therefore, discriminate between the metal wanted for light, medium, and heavy castings at a glance, and without making a comparative calculation, the results of which are open to doubt.

The German specifications for casting test-bars go us one better in requiring the vertical pour, but from bottom up. We await their results on this with interest, as we use the ordinary top pour, but so arranged that the metal drops to the bottom through funnel-shaped gates, and the mold is thus made cheaper.

German specifications require the bars to be made in flasks that are not parted, if possible, so that the test-bars have no seams. If, however, this is unavoidable, the test-bar is to be so placed that when tested, the seam lies in the neutral axis. We prefer to prevent the making of test-bars with seams altogether, by giving complete specifications for the flask itself, which any foundry can arrange for without particular trouble.

Both specifications agree in having the bars cast in dry sand,

and the cooling of the bars in the flask. Furthermore, only brushing is allowed in cleaning the bars, and no machining is to be done.

In judging the tests themselves there is a difference between the two specifications in question. We specify just when the tests are to be arranged for in the heat, and that one of the two bars cast at the various casting intervals must pass the requirements. The German specifications call for three bars, the average of which must be taken, defective bars to be excluded. In both cases the expense of testing falls upon the founder. In our added tensile test, this, when required by the purchaser, is to be paid for by him.

The clause in our specifications wherein we allow the buyer the freest run of our establishments, in order to convince him of the quality of work being turned out, does not appear in the German specifications. Only in the case of pipe is there mention made of facilities to be given the inspector to watch the testing of the material.

It is still a little early to draw conclusions from the specifications advanced, for they are either not officially adopted, or are still in their trial stage. This much can be said, however, that a marked advance can be recorded, for in everything presented so far, the attempt has been made to build on our increasing knowledge of the properties of cast iron as a metal. Much has, of course, to be yielded to business expediency, for the industrial customs of a nation cannot be radically disturbed without laying ourselves open to the charge of being idealists and dreamers.

The buying of pig iron by analysis, and now by specification, may be said to be the most radical step ever taken in the foundry. The adoption of specifications for castings is gradually coming into vogue also, and we will soon see the allied industries, such as fuel, sand, facings, etc., become a subject for study and final specification.

It is to be hoped that at Brussels next year, we may not only report final specifications for all that we have undertaken in the way of cast iron, but that Germany, England, France and Austria may be similarly situated. Then we can compare notes, and possibly adjust some of the items so as to have a greater conformity in practice

DISCUSSION.

Mr. Wille.

MR. H. V. WILLE.—If iron foundries would follow the same system as steel furnaces, of judging heats by fractures before the heat is poured they would no doubt get equally good results. The system would have to be developed and men would have to be trained in the art, but it could readily be done by making a series of chill test blocks and comparing the fracture with the analysis. A series of such fractures could be kept in the foundry as standards properly labeled with the chemistry and physical properties with which the workman could compare the fracture of tests from various heats. With a little experience the foundryman would thus know the quality of the iron before pouring important castings. By following some such method as this, the foundryman would be able to regularly work to specifications without incurring an unusual percentage of rejection that is sure to follow the hit-or-miss methods employed in many foundries.

Mr. Moldenke.

MR. RICHARD MOLDENKE.—In some lines of our work this is done, especially in the manufacture of chilled rolls, or such furnace work where the silicon is low. In "malleables," where the silicon is lowest, we make a regular "plug test" before the heat is cast. When we come to the high silicon range, the matter becomes more difficult. It seems that in malleable practice, where we cast a plug about an inch and a half in diameter, and about six inches long, in the sand, the fracture is perfectly white when the silicon is below 0.35. When it is between 0.50 and 0.60, the fracture is slightly mottled, and for silicon from 0.85 to 1.0 it is almost gray. This was distinctively the case years ago, when every malleable works was run on the same lines, and with charcoal iron. When, however, we started the introduction of steel scrap into the malleable practice, and even added gray iron scrap, if the heat was at all in shape to receive it, this mottling was wiped out. I found that iron with silicon as high as 0.80 in the heat, cast in plugs, is dead white. You could only tell by the peculiar shape of the crystals, whether the melt had the right temperature.

If oxygen was present the whole of the crystallization was wiped out, and we had a mushy fracture to deal with. The only thing to do then was to see if there were little pin holes around the edge. When we knew the heat had gone too far, we made plain castings, unless these were important, in which case we cast the heat into pigs and used it over again. **Mr. Moldenke.**

For purposes of specifications, or testing to find out what the metal is, we would like to have the metal under the finest conditions possible. Even the very best of metal can, however, be spoiled in the castings if there is trouble on the foundry floor.

THE THERMIT PROCESS IN AMERICAN PRACTICE.

By ERNEST STUETZ.

Just a year ago the first Thermit was manufactured in this country and the applications developed in Europe by Dr. Hans Goldschmidt, at the works of Th. Goldschmidt, Essen-Ruhr (founded 1847), were transplanted to American soil and have since blossomed forth under the fostering care of American ingenuity.

The principle of the Thermit process can now be said to be known to the technical world, and it will be sufficient to state that through the ignition of finely divided aluminium and metallic oxide, a reaction is started which produces heat of about 5,400° F. and at the same time reduces the iron oxide to a metallic iron almost free from carbon, in a highly superheated liquid state. Thermit steel has practically twice the temperature of open hearth steel, and a correspondingly greater fluidity. By suitable additions of carbon, in the form of steel punchings, chilled iron shot or ferro-silicon, its hardness, and by addition of manganese, its toughness can be increased to any suitable degree.

The following analyses will confirm this.

The first is one of pure Thermit steel; the other of the steel in the riser of a welded steel locomotive frame, drawn out under the hammer into a bar some three feet long and turned down and broken.

ANALYSIS OF THERMIT STEEL. ILLINOIS STEEL CO., THE ROOKERY, CHICAGO, ILL.

CARBON	MANGANESE	SILICON	SULPHUR	PHOSPHORUS	ALUMINIUM
0.05	0.10	0.204	0.04	0.05	0.18

Tensile Strength, lbs. per sq. in.	Elongation.	Contraction of area.
59320	25.33%	59.6%

PENNSYLVANIA RAILROAD, ALTOONA.

Thermit Steel with Addition of 2% Carbonless Manganese 5% Iron Punchings (Calculated on Amount of Thermit).

Carbon	Manganese	Silicon	Sulphur	Phosphorus	Aluminium
0.102	2.330	1.227	0.034	0.070	....

Tensile Strength, lbs. per sq. in.	Elongation. per cent in 8 inches.	Appearance of Fracture.
91600	21.5	Silky.

The simplicity of outfit and manipulation and the speed with which the reaction does its work are its chief recommendations for industrial purposes.

In a crucible some 20 inches high and therefore easily transportable, in half a minute can be produced 30 pounds of liquid steel, so hot that it will melt a steel bar of 4-in. square section and fuse with it to one homogeneous mass.

The essential characteristic of Thermit is that it welds by fusion, and by reason of this fact, calls for the foundryman's experience more than the blacksmith's. Its success depends on the proper material, shape and condition of the mold.

The mold into which the contents of the crucible is run must be of refractory material, The general instructions must of course be broad and cannot go beyond stating that a mixture of equal parts of sharp sand and ordinary brickmakers' clay has given satisfaction. The formula has been varied sometimes, according to local conditions, in some cases flour, in the proportion of 6 to 100, being used as binder for the sand. Some shops have already evolved their own particular formulas, which they treat as secret. The mold always must be dry—*burnt* dry. In some cases, for instance, at the Elkhart Shops of the Lake Shore & Michigan Southern, the difficulty has been overcome by using fire-brick cut down to size. This certainly overcomes the question of drying molds.

The shape of the mold must next be considered. It must be so constructed that the steel flowing down through the gate will not strike direct on to the casting or forging, but will flow underneath the lowest part and rise around and through it. What is required is good circulation for the Thermit steel. It must flow around all the welding surfaces and as it gets chilled in contact

with these, it must be driven up into a riser and be followed by a sufficient supply of fully heated Thermit steel to effect the actual weld, which takes the shape of a collar or reinforcement, cast on or over the fracture.

The mold must therefore allow (1) for a gate, (2) for a collar, shoe or other reinforcement on the surface of the welded piece and overlapping the edges of the break or joint, (3) a riser, (4) a skim gate, to prevent the slag from getting mixed with the steel.

The formula for calculating the amount of Thermit must also allow not only for the cubic space of this reinforcement, but

BREAK OF WELDED BAR, $2\frac{1}{2}$ x $2\frac{1}{4}$ IN., AFTER PRESSURE OF 50 TONS.

further, for again as much Thermit, to supply the contents of gate and riser.

These are the general instructions for welding, for instance, *Locomotive Frames*—a problem which some thirty railroads in this country have investigated with more or less success. These frames are of wrought iron or cast steel and vary from $3\frac{1}{2}$ x $3\frac{1}{2}$ in. to 5 x 6 in. in section. They are very liable to break and their repair without dismantling the engine means a very large saving per engine. It has been stated that an engine, the frame of which is repaired in the forge, remains a fortnight out of commission and

the actual weld costs $250.00 to $300.00. The work by Thermit can be done comfortably in three or four days, at a cost of about $50.00.

In reply to a circular letter of inquiry, about twenty railroads have supplied data, which, however, cannot be considered complete, as some of the most regular and extensive users of Thermit did not care to supply the information asked for.

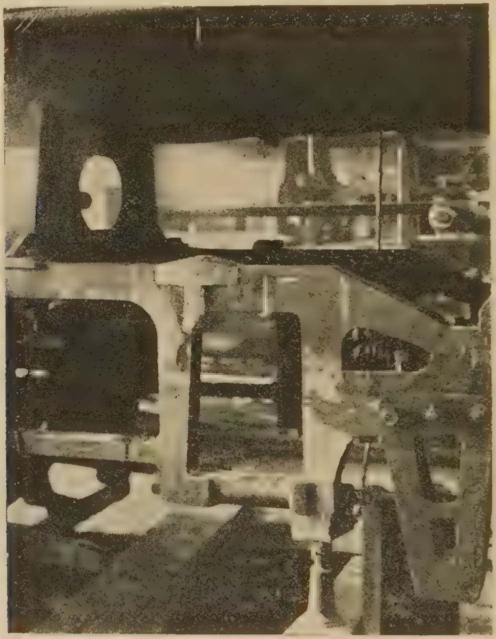
The first successful weld it has been possible to get a record of was made by Mr. Sanderson, Superintendent Motive Power,

WELDING LOCO FRAME: READY FOR IGNITION.

Seaboard Air Line, on October 19, 1904. This engine has continued in service ever since. It is one of eight engines welded on that road which has given satisfaction, which speaks highly for the care used at the Portsmouth shops in handling a new and therefore difficult problem.

Another series of successful welds is reported by the Boston & Albany Line, where Mr. Fries welded five engines quite successfully—one being in continuous service since the end of November. One, welded in the jaw, broke again, but four inches away from the weld.

Of late the Lake Shore & Michigan Southern has shown great interest, and its perseverance has been crowned by success in some very good welds at their Elkhart shops, about which Mr. Webb read a very interesting paper at the last annual meeting of the American Foundrymen's Association, giving a full account of each step in the operation. On a preliminary test, a welded bar $2\frac{1}{2} \times 2\frac{3}{4}$ in. stood a pressure of 50 tons on supports 20 inches apart, before



LOCO FRAME: WELDED IN THE JAW.

breaking, and that, after two sides of the reinforcing collar had been machined off.

In all there are records of thirty engines with welded frames that have been in service for three months or longer. Failures are recorded only in isolated instances and are assignable to three different reasons:

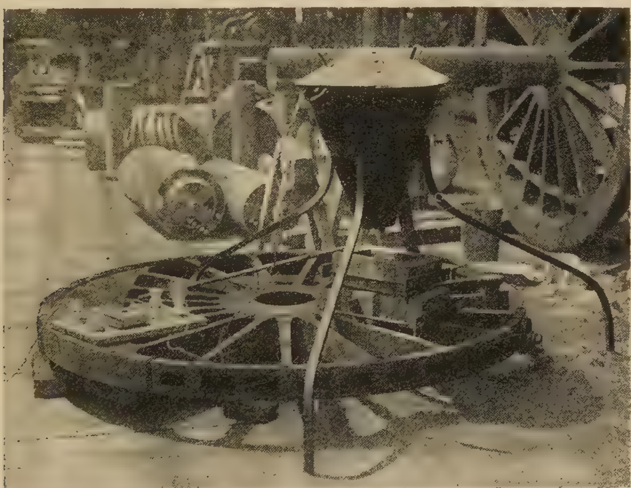
First, wrong construction of mold.

Secondly, insufficient Thermit; in other words, insufficient circulation—therefore, insufficient fusion.

For those familiar with the process, a weld that breaks on account of lack of cohesion at the welding surface is attributable under all circumstances to lack of experience or care, except in one particular case.

It is possible for Thermit welded frames to break in spite of proper execution of the work. The original break is due, in the first place, to a structural defect. With the break in such a position as to necessitate the entire removal of the reinforcing collar, it is too much to expect the mere bridging of the broken ends by Thermit steel to overcome this innate weakness.

An important factor in success in welding locomotive frames



WELDING SPOKE OF LOCOMOTIVE DRIVING WHEEL.

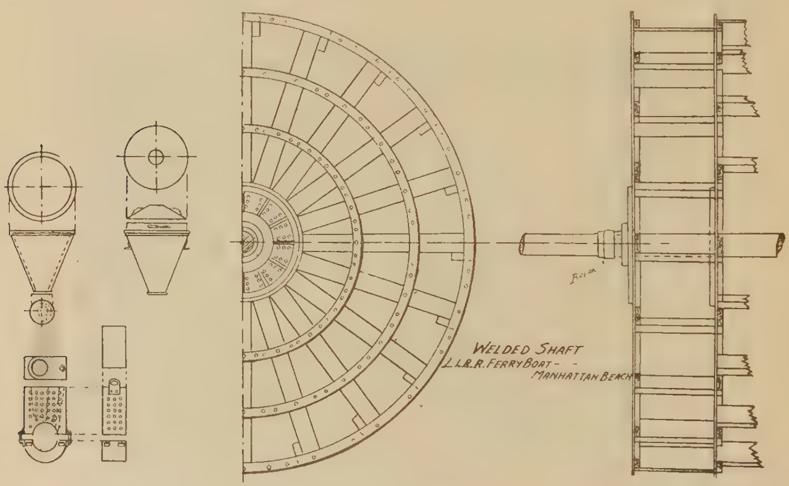
is to allow for equal shrinkage of parallel parts; also, wherever possible, to spread the ends apart in order to let them come back when the iron begins to set.

Another operation of interest to railroad men is the welding of spokes of drivers.

In making tests of the metal of such welds, the Chicago, Milwaukee & S . Paul R. R. found a tensile strength of 93,900 lbs per square inch. The analysis agreed with that of the Pennsylvania R. R., with the exception of manganese, which in this case was only 0.74.

Next come repairs in *Marine Engineering*, which are mostly successes obtained by Mr. Des Anges, Superintendent floating Equipment of the Long Island R. R.

A 12 inch crank shaft ($13\frac{5}{8}$ inches at point of fracture) of the ferry-boat "Manhattan Beach" was welded with 400 lbs. of Thermit. The break was in the "wheel center," necessitating the shifting of the center to a new position and shortening the paddle boxes. The shaft was pre-heated by a charcoal fire and hand-blower, to black heat. To protect the woodwork of the ferry-boat, an asbestos curtain was hung around the crucible, which



Scale $\frac{1}{8}'' = 1$ foot.

WELD OF CRANK SHAFT "MANHATTAN BEACH."

served its purpose admirably. The ferry-boat has been in uninterrupted service for nearly three months, and continues so now.

A rudder-stock, 5 inches in diameter, was welded with 50 lbs. of Thermit and 10 lbs. of punchings. The collar in this case had to be entirely removed, but the welded rudder-stock has now been in service for eight months.

On the Great Lakes, through the enterprise of Capt. Johnson, at that time with Dunham Towing & Wrecking Co., the rudder-shoe of the tug boat "Schenck" was welded, 125 lbs. of Thermit being used. The weld was sound—in replacing the propeller,

a chain broke and the propeller dropped on the welded shoe without injuring it.

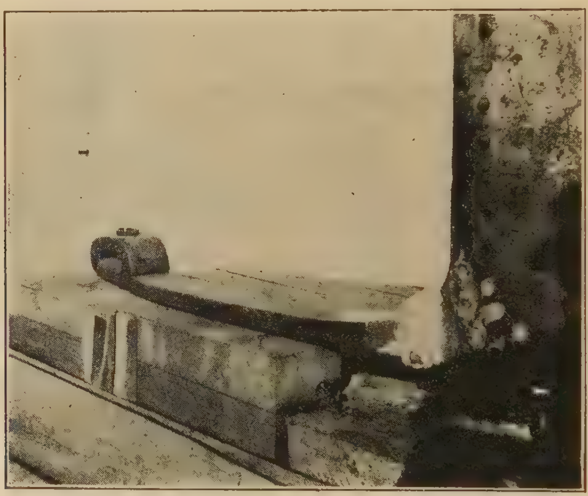
Some important repairs of *Gray Iron Castings* are also reported. At the Renovo shops of the Pennsylvania R. R. a hydraulic wheel press was repaired, the part welded having to stand a pressure of 60 tons per square inch. The original "strong back" holding the wheel against which the axle was pressed was not strong enough for the purpose until repaired by Thermit.

WELD OF 5-IN. RUDDER STOCK.

Cylinder covers are also repaired by Thermit and have been made as good as new.

Work with gray iron castings requires more experience, in regard to pre-heating and cooling down gradually—more Thermit is necessary to affect the weld, on account of a hard, glassy scale on such castings, which resists fusion, and an addition of ferro-silicon (about 2 per cent.) is advisable to prevent hard spots at the lines of junction between Thermit steel and cast iron.

The most important application of the Thermit process is for making a *Continuous Rail*. The process having been brought to a high state of perfection in Europe before coming here, there was little room for changes in practice. About thirty different cities are investigating the process in actual operation and about 5,000 joints have been put in up to date. All these roads recognize in the Thermit process the best and simplest means of joining rails for electric traction, as long as care is taken to do small and simple things right. Competitors in the field of rail-welding may send out



WELDED RUDDER SHOE TUGBOAT "SCHENCK."

fanciful blue-prints about broken joints, to create unfavorable impressions, but such maneuvers prove nothing beyond the fact that they admit the success of the Thermit process in this field.

Some tests may be of interest. A heavy double trolley car was taken over a welded joint with supports 13 feet away, without breaking it.

To decide whether the head of the rail got softer, micrometer caliper measurements were taken of depressions made under equal blows of a steam hammer, by a blunt tool hardened at the head, ¼ inch in diameter.

One-half inch away from the joint the depression was 0.1432 inches.

Three feet away from the joint the depression was 0.1596 inches.

The electric conductivity of the Thermit joint is recognized to be higher than that of the rail, due to increase of area, and is permanent.

That *Steel Foundries* should have been the first to recognize the possibilities of liquid steel that can be produced anywhere in half a minute, goes without saying. There are already several

WELDING TROLLEY RAIL AT HOLYOKE, MASS.

of the largest with whom Thermit is as much a necessity as foundry sand. Some prefer—for no apparent reason—not to disclose the fact that they repair faults in castings by Thermit, but all can openly admit they use it to reduce the size of their risers, an application which, through its simplicity, recommends itself to all foundries—gray iron as well as steel. Thermit thrown loosely or in a paper parcel on steel, will ignite and keep the contents of the riser fluid even after the metal has become plastic in the casting. Liquid cast iron will only ignite Thermit in the presence of the ignition powder.

The application of Thermit to *Reduce the Piping in Ingots*, although very simple in itself, necessitates some liquid steel being held in readiness to fill up the piping after the solidification has been interrupted by a Thermit reaction. This should not be impossible to arrange.

RIEHLE BROS., TESTING MACHINE CO. TESTS ON MALLEABLE IRON BARS CAST AT PENNSYLVANIA MALLEABLE CO.'S WORKS, McKEES ROCKS, PA.

Before Titanium Thermit Reaction.

	Dimensions.	Ultimate Strength, Pounds.	Deflection.
No. 1—1	1.000 x .999	4,100	1.00″
1—2	.995 x .999	4,500	.98″
1—3	Lost in anneal.		
2—7	1.060 x .998	4,540	1.28″
2—8	1.012 x 1.006	4,610	1.40″
2—9	1.006 x 1.005	4,500	1.40″
	Average before treatment	4,450	1.212″

After Titanium Thermit Reaction.

	Dimensions.	Ultimate Strength, Pounds.	Deflection.
No. 1A— 4	1.011 x 1.010	5,920	1.30″
1A— 5	.999 x 1.000	4,260	1.27″
1A— 6	.989 x .995	4,850	1.55″
2A—10	.995 x .996	4,620	1.47″
2A—11	.998 x .996	4,410	1.37″
2A—12	1.011 x 1.000	4,810	1.44″
	Average after treatment.	4,811	1.60″

Another branch of alumino-thermics which will be of interest, is the *Improvement of Gray Iron Castings*, by the introduction of Titanium Thermit in the ladles, by immersing it in a cartridge below the surface of the metal. Some experiments, thanks to our fellow-member's, Dr. Moldenke's, kind intercession, were made at the Pennsylvania Malleable Works, with the foregoing results, the bars having been poured out of the same ladles, one before, the other after, the Titanium Thermit reaction.

Experiments with lower grades of iron showed the same favorable results.

At the Featherstone Foundry, Chicago, Titan Thermit treated test bars showed a tensile strength of 3,550 lbs., against average untreated, 3,250 lbs. The metal, after treating, is much denser, but can be easily machined. Incidentally, it may be mentioned that by the introduction of a $1\frac{1}{2}$ lb. cartridge of ordinary black Thermit into an 800 lb. ladle, 40 lbs. of steel borings can be melted without difficulty.

WELDING RUDDER STOCK OF TUGBOAT "SCHENCK" ON MARINE RAILWAY, SAULT STE, MARIE.

This necessarily very short account of what is doing in Thermit cannot, of course, cover the entire field of the applications, but will perhaps tend to convince those who had rather be guided by results obtained elsewhere than spend time and money on what they think experiments, and encourage others who are doubtful from lack of experience, by showing them what has been accomplished in actual practice.

DISCUSSION.

Mr. Moldenke.

MR. RICHARD MOLDENKE.—I was very much interested in these experiments, especially as they would show the effect of any possible removal of oxidation in the metal. My impressions, gathered from many years of experience with low-silicon cast irons, are that any process of melting means a greater or less accumulation of oxides in the bath, which are not entirely removed by the reaction with the carbon present. The temperature is not usually high enough for this. Consequently, it is necessary to add deoxidizing agents, such as ferro-manganese, ferro-silicon, aluminum, etc. Now in steel, the temperature is so high that an immediate reaction takes place, and the bath may be considered pure, so far as oxides are concerned. Not so, however, with cast iron, and we are to-day looking for an iron alloy which will do for cast iron what ferro-manganese does for steel. Aluminum, while excellent for the gray irons, is not suitable for the low-silicon white ones, as it promotes the formation of graphite. Ferro-silicon, and ferro-manganese are not active enough in the temperature attained, and hence the use of thermit with titanium in it seems to me to offer a neat solution of the difficulty, provided only that the price is not prohibitive. In the experiments in question, the metal treated was in itself of so high a grade, that but little improvement is shown. Had, however, the usual run of iron been experimented with—the kind one gets in foundries not alive to the best practice—the showing would have been quite different. It is certainly to be hoped that, where important work is at stake, foundries will not only make use of a method which will give them very hot metal, but which will also purify it, and hence raise the strength very materially.

Mr. Stuetz.

MR. E. STUETZ.—The putting of nickel into cast iron has been practiced in Germany for the purposes Dr. Moldenke mentions. It has been found that the cast iron, having an addition of one-half per cent. of nickel, will increase the life of these alkali pots by about 50 per cent. The introduction of nickel into cast

iron has been a difficult point up to the present time, because it has been hard for the foundry to have necessary furnaces for the nickel. Dr. Goldsmith has made nickel thermit like iron thermit, which by reducing the action of the aluminum produces a nickel in a fluid state at a high temperature. Mr. Stuetz.

We had an opportunity the other day of showing the application of this addition, or treatment of nickel and cast iron, at Harrison, N. Y. The operation is simple. The nickel thermit is ignited in a well-lined ladle, and all of the liquid nickel with the slag is poured into cast iron. What difficulty there is lies in the fact that nickel is as hard to distribute evenly through the metal as carbon. For that reason we use Titanium Thermit, which causes an automatic poling action, whereby the liquid nickel and slag introduced into the liquid cast iron are distributed throughout the metal. The Titanium Thermit can be fastened to the end of a shank and any man can stick it into the metal and hold it there, putting the whole bath into seething motion and effecting the even distribution of the nickel through the metal, the slag being driven out at the same time.

THE PRESIDENT.—It may not be amiss to call attention to the fact that the thermit reaction seems to offer a means of studying what up to the present time is practically an unsolved problem, namely, the influence of each of the constituents affecting iron and steel, on its physical properties. Mr. Metcalf can give us some very interesting history of an attempt made some years ago to make several series of steels, differing from each other in one constituent alone, so that the influence of that constituent could be determined. This subject has likewise been studied a good deal by Professor Arnold at Mr. Hadfield's foundry in Sheffield, and it is a query whether several series of steels obtained by the thermit reaction could not well be made the subject of further study. The President.

MR. WILLIAM METCALF.—When the Government appointed a Commission, many years ago, to make a series of experiments at the Watertown Arsenal—I have forgotten the names of some of the men; but I remember Admiral Beardsley, Alexander Holley and Prof. R. H. Thurston—we undertook to make a series of steels which would be uniform in all elements but one, in which case that one element should be increased from a trifling amount to a very large percentage. We had no difficulty in making the Mr. Metcalf.

Mr. Metcalf. carbon series running from about 20 to 150, with phosphorus, silicon and manganese practically uniform and very low. We also succeeded in making a fairly good silicon series and phosphorus series. I have forgotten whether we got to the sulphur. I think not. We tried to make a manganese series, but found it utterly impossible to do so in the carbon pot, for the reason that no matter how we melted it, or how we tried, we always got high carbon with manganese. We would start with low carbon and change that slowly—and in this case, I think, we used a uniform quality of Swedish iron carefully analysed—and then added the elements we wanted. We could get, of course, the first sample of low carbon with low manganese, but as we added a little bit of manganese—just as surely as we added any at all—we added carbon, no matter how we began. Professor Langley decided it would be impossible to do this except in the open-hearth furnace where there would be an entire absence of any sort of carbon except that which might be produced purposely. That we intended to carry out, but, unfortunately, at that point Congress refused to make any further appropriation and the matter was dropped. The fact remains, if you want a manganese series you have got to do it in some medium where you can keep the carbon away, or the manganese will take the carbon in spite of anything you can do. That can be had in the thermit process very easily and economically, and, in that way you would get what would be valuable for all of us to have, a real series varying in the percentage of manganese only, so that we could know the different results.

Mr. Stuetz. MR. STUETZ.—It may be interesting to state that we have made, on a small scale, some experiments with varying additions of manganese, but it may be that the tests were not elaborate enough. We found that even using carbonless manganese, no definite results could be arrived at. We could get the carbonless manganese to alloy with the steel but about one-half the manganese would disappear. These experiments, however, were by no means conclusive.

PIG IRON GRADING BY ANALYSIS.

By Hambden Buel.

A year or more ago the writer received from the American Foundrymen's Association a reprint from its "Journal" on "Methods of Determining the Constituents of Cast Iron." It was the result of long and very careful deliberation to arrive at a system of uniform methods for pig iron analysis. Needless to say the object was one deserving of the highest consideration and the support of all interested. However, I must say that I was at the time very forcibly impressed with one point—Would the adoption of such standard methods of pig iron analysis eradicate the differences met with among pig iron makers and consumers? While I do not criticise the adoption of standard methods of pig iron analysis, I believe the case should be thoroughly diagnosed before treating and then the proper remedy applied. The error into which so many fall is in believing that some road is better than no road. I believe that no road would be better, as then one would be inclined to be more careful. With the foregoing points in mind, the writer a few months ago undertook some investigations relative to differences in pig iron analysis. Our company decided about the first of the year to abolish fracture grading and grade all iron by analysis, virtually accepting the basis of grading as recommended by the American Society for Testing Materials.

The handling of iron at the plant of the Central Iron and Coal Company with which the writer is connected, is somewhat different from the practice at most furnaces. In the first place, our iron yard is practically a continuation of the cast house and is traversed by a traveling crane with a span of about 60 feet. The columns supporting the runway of this crane are 25 feet from center to center. As soon as a cast has cooled somewhat the beds are carried out bodily and placed upon the iron yard, each cast being placed separately and marked with the cast number and date. The next day the cast is laid out upon the ground and broken by means of sledge hammers. The pigs are picked up by hand into

TABLE I.—ANALYSES OF SHOT, PIG AND CAR LOT SAMPLES.

Grade by Silicon.	Lot No.	Average Shot Analysis.		Average Pig Analysis.		Average Car Analysis.	
		Silicon.	Sulphur.	Silicon.	Sulphur.	Silicon.	Sulphur.
1.25	1	1.19	0.079	1.15	0.117	1.31	0.122
1.25	2	1.04	0.063	1.05	0.082	1.21	0.080
1.25	3	1.19	0.063	1.20	0.093	1.20	0.073
1.25	4	1.33	0.039	1.30	0.038	1.83	0.056
1.25	5	1.26	0.049	1.28	0.083	1.51	0.050
1.75	1	1.91	0.072	1.88	0.091	2.01	0.111
1.75	2	1.87	0.061	1.89	0.087	2.07	0.080
1.75	3	1.70	0.040	1.57	0.057	1.94	0.056
1.75	4	1.76	0.043	1.79	0.052	1.77	0.060
1.75	5	1.71	0.025	1.75	0.033	....	.....
1.75	6	1.69	0.024	1.68	0.027	1.91	0.040
1.75	7	1.58	0.038	1.52	0.045	1.80	0.065
1.75	8	1.85	0.018	1.82	0.026	1.81	0.040
1.75	9	1.85	0.025	1.84	0.031	1.91	0.055
1.75	10	1.97	0.041	1.90	0.050	....	.....
1.75	11	1.81	0.029	1.80	0.034	1.63	0.044
1.75	13	1.93	0.036	1.97	0.034	1.83	0.049
1.75	14	1.72	0.024	1.72	0.025	....	.....
1.75	16	2.08	0.062	2.01	0.074	....	.....
2.25	1	2.33	0.048	2.34	0.053	2.33	0.054
2.25	2	2.18	0.120	2.20	0.132	....	.....
2.25	3	2.18	0.044	2.15	0.058	2.19	0.060
2.25	4	2.21	0.039	2.05	0.051	2.32	0.046
2.25	5	2.22	0.047	2.43	0.059	2.23	0.081
2.25	6	2.27	0.027	2.23	0.028	2.38	0.032
2.25	7	2.26	0.017	2.15	0.022	2.51	0.022
2.25	8	2.21	0.028	2.15	0.036	2.43	0.069
2.25	9	2.26	0.034	2.25	0.034	2.34	0.037
2.25	10	2.12	0.033	2.19	0.039	2.11	0.044
2.25	11	2.26	0.032	2.20	0.037	2.27	0.038
2.25	13	2.28	0.055	2.19	0.088	2.24	0.076
2.25	16	2.23	0.044	2.25	0.049	2.07	0.039
2.75	1	2.86	0.037	3.01	0.048	3.05	0.051
2.75	2	2.80	0.036	2.66	0.054	2.75	0.052
2.75	3	2.86	0.031	2.47	0.044	2.56	0.035
2.75	4	2.82	0.021	2.97	0.024	2.76	0.028
2.75	5	2.66	0.025	2.37	0.040	2.61	0.040
2.75	6	2.73	0.027	2.64	0.033	2.60	0.042
2.75	7	2.82	0.026	2.49	0.043	2.57	0.045
2.75	8	2.84	0.021	2.72	0.036	2.85	0.030
3.00	1	2.96	0.069	2.79	0.075	2.89	0.083
3.00	2	3.18	0.060	3.06	0.077	3.10	0.064
3.00	3	2.96	0.050	2.92	0.062	3.07	0.064
3.00	4	3.12	0.052	3.06	0.073	2.96	0.069
3.00	5	2.89	0.044	2.76	0.054	2.75	0.047
3.00	6	2.88	0.044	2.87	0.058	2.92	0.052
3.00	7	3.14	0.033	2.77	0.033	2.80	0.034
3.00	8	3.04	0.024	3.04	0.028	2.88	0.035
3.00	9	3.07	0.021	2.92	0.025	2.84	0.031

TABLE I.—ANALYSIS OF SHOT, PIG AND CAR LOT SAMPLES—*Continued.*

Grade by Silicon.	Lot No.	Average Shot Analysis.		Average Pig Analysis.		Average Car Analysis.	
		Silicon.	Sulphur.	Silicon.	Sulphur.	Silicon.	Sulphur.
3.00	12	2.99	0.046	2.81	0.067	2.74	0.081
3.00	13	3.03	0.039	3.09	0.064	2.93	0.082
3.00	15	3.45	0.061	3.09	0.084	....	.....
3.00	17	3.03	0.023	2.92	0.037	2.73	0.051
3.00	18	2.92	0.027	2.61	0.048	2.53	0.040
3.00	19	3.25	0.047	2.98	0.059	2.81	0.060
3.75	1	3.75	0.033	3.62	0.046	3.57	0.041
3.75	2	3.69	0.029	3.67	0.042	3.76	0.036
3.75	3	3.75	0.027	3.49	0.044	3.35	0.046
3.75	4	3.90	0.035	3.43	0.063	....	.....
3.75	5	3.84	0.036	3.67	0.052	....	.....
4.25	1	4.27	0.035	4.16	0.040	4.24	0.036
4.25	2	4.12	0.038	3.79	0.061	4.09	0.045
4.25	3	4.27	0.026	3.93	0.029	3.87	0.052
4.75	1	4.75	0.040	4.38	0.046	4.39	0.041

steel boxes holding about 2 tons and dumped by means of a crane into blocks, according to analysis. These blocks are located between the columns of the runway and hold when complete 300 to 350 tons of iron. When a block is completed it is opened for shipment and the analysis computed from the analyses of the several casts entering into it.

The procedure in the investigation consisted of three steps: First, sampling each cast by the shot method, taking nine dips uniformly throughout the cast; second, taking a sample of six pigs from the same cast, and, third, sampling each car loaded from the respective mixtures. The nature of the investigation was such as to necessitate its extending over a considerable period, as a few isolated instances would be practically worthless. A complete record was kept of the cast analyses, both shot and pig samples, from January 25, when the furnace was blown in, to May 15, when it became necessary to suspend the investigations on account of the burning of our machine shop, where our pig samples were drilled.

Table 1 is a record of the mixtures of iron, showing the average upon both the shot and pig sample basis, together with the average of the cars loaded out of the respective mixtures, and embraces a total of over 16,000 tons of iron of all grades.

A tabulation of 368 casts, giving both the shot and pig sample analyses, showed that in 45.92 per cent. of the cases there was a variation of less than 5 per cent. in the silicon content of the shot and the pig samples of the respective casts; in 23.91 per cent. of the casts a variation of from 5 to 10 per cent.; in 21.19 per cent. of the casts a variation of from 10 to 20 per cent., and in 8.97 per cent. of the casts a variation of over 20 per cent. Out of this total 31.25 per cent. showed that the silicon content of the pig sample was higher than in the shot samples.

The results of the sulphur contents were not nearly so gratifying, the shot sample yielding invariably lower sulphur than the pig samples. In 39.67 per cent. of the cases the difference was 0.01 or less, in 27.99 per cent. the difference was between 0.01 and 0.02 and in 32.33 per cent. the difference was above 0.02. The writer has attempted to compare the result of this exhibit with the burdening, blowing, blast pressure, atmospheric humidity, variations in blast and gas temperatures, presence of water, and irregular furnance working, but in the absence of any very definite conclusions will not essay to present the comparisons in this paper.

Table 1 herewith is most interesting and comprehensive. I would call attention to the three different sets of average analyses, especially in respect to the silicon content. Out of 432 cars shipped and embodied in this exhibit a little less than 13 per cent. showed a variation of between 10 and 20 per cent. above or below the computed silicon content of the respective mixtures, while about 2½ per cent. showed a variation above 20 per cent. In every instance the discrepancy was traceable to mixtures containing casts which showed the wider variation in silicon content of the shot and pig samples. The method then in vogue of mixing was not sufficient to overcome this effect. To explain this: The outer wall of the block was from 8 to 10 feet beyond the perpendicular to the track of the crane runway. Thus in dumping the boxes of iron into the block they would lack five or six feet of reaching the outer edge of the block, making it impossible to distribute the iron as uniformly as desired throughout the block. A thorough discussion of the variations in sulphur is omitted, as I believe it wiser to try to solve one point at a time. Furthermore, the solving of the one question will help in the solving of the other.

The record of the 368 cast analyses corroborates the frequent

experience of a single cast of iron varying widely in its silicon and sulphur contents. Some years ago the writer had occasion to investigate the variations and segregation of the elements and metalloids in iron and steel, and one instance came to his notice of a single half pig showing a variation of 1 per cent. (100 points) in silicon in the drillings taken from different parts of the half pig. If this be possible, where shall we look for a remedy—in the furnace or in the resultant product? A number of factors are involved in furnace operation, any one of which might be influential in effecting the variation of the silicon or sulphur contents of an individual cast, and all of which are beyond the furnaceman's control. The action of the iron in a furnace as it comes down from the zone of reduction into the hearth of the furnace might be compared, I think, with the action of dropping very gently into a vessel of molten substance of high specific gravity some molten substance of like specific gravity. The two will not become thoroughly mixed. If it were possible to devise some means by which the metal in the hearth of the furnace could be mechanically mixed the resulting cast would probably be found more uniform, except for the carbon, as this would still be affected by the difference in the chill.

On the other hand, if we were to look to handling of the resultant product for a corrective of the differences I believe we would be taking a more reasonable course. With this in mind the writer made a change in the manner of mixing the iron entering into the various blocks, though this was done at the expense of 5 or 6 feet of space on either side of the iron yard. So now the iron entering into any specific mixture is distributed evenly throughout the surface of the block, and a block when completed might present the appearance of a huge square layer cake of which the carloads are the slices.

HARD CAST IRON: A THEORY OF ONE OF ITS CAUSES.

By Henry Souther.

A consulting metallurgical engineer in contact with machine shops is accustomed to hearing complaints from the operators of machine tools of hardness of material being machined. Sometimes it develops, especially with steel, that the trouble is not that the steel is hard, but, on the contrary, that it is exceedingly soft. The softness is of such a character that the edged tool does not succeed in cutting the steel keenly, but rather tears it off, some of the particles clinging to the edge of the tool, causing excessive friction and rubbing, and drawing the temper of the tool and dullness soon follows. The effect, as far as the machine operator is concerned, is that of a hard steel; the tool is spoiled. This not only applies to low carbons but to a peculiar physical condition of higher carbons, say, in the neighborhood of .50, due to bad annealing.

Then there is the legitimate hard steel, which is really hard in the true sense of the term.

Cast iron that chills may be called hard in the truest sense of the word. That is the complaint that is most often met when the term hardness is used in connection with machining cast iron. Iron chills because of high sulphur or low silicon, or a combination of both, and machine tools simply cannot cut it. This kind of hardness is more often found in thin work than in thick work. For example, the hardware people casting very thin material have to use the softest of iron, high silicon and low sulphur, in order that the small amount of machining they do may be done at all.

In the last five or six years three separate complaints of hard iron have reached the writer and proved of so baffling a character that in each case visits were made to the machine shops working the iron, and the complaint carefully investigated. Analysis or test did not reveal the cause.

The most instructive case covers them all. This instance

was most instructive because it occurred on a multiple drill where several different sizes of standard drills were used and several thicknesses of metal were involved. On approaching the machine it was noticeable at once that there was trouble, because the drills were screeching in an unusual way.

It developed that small drills, $\frac{1}{4}$-in, or thereabouts, were standing up with this iron just as well as any other, but the larger drills in the neighborhood of $\frac{1}{2}$-in. and $\frac{3}{4}$-in. were dulling exactly as though the iron were charged with emery. The edges were being ground off and would last only a fraction of the time usual for the same drills in the same machine.

Here was an unusual condition, thin iron working easily, thick iron on the same castings working with difficulty.

The chemical results were normal, except manganese: Silicon 2.50, phosphorus .70, sulphur about .080, total carbon 3.50 and manganese .16.

The fracture of the iron was good and, moreover, it was quite normal as far as could be seen with eye or microscope. A Keep's test drill was used and developed nothing unusual, no signs of hardness, thick and thin iron showing a normal curve. There was no opportunity to test the tool-wearing qualities on the Keep machine, because the drill was sharpened after every hole drilled.

Inasmuch as the only abnormal part in the analysis was shown in the manganese, that element was suspected, although there seemed to be no metallurgical reason for so doing. Means were taken to raise it to the neighborhood of .50 and as soon as this was done the difficulty disappeared in the machine shop and has not reappeared after some months.

It is a complaint which reached me, as I said above, from two other sources, and in both of those sources the complaint was described by the machine-shop people by saying that the iron was "gritty." They were fully convinced that there was sand in it, but examination showed that to be out of the question, and the iron was as clean as any iron.

This leads me to believe that there must be some carbide of iron or carbide of silicon that forms in the absence of a reasonable amount of manganese, and that does not form with manganese present. What this chemical combination may be I cannot surmise, but the problem presented is an interesting one from a theo-

retical and practical standpoint. Apparently its cure has been found, but the question remains—why?

The actual castings causing this trouble were put through and no specimens kept, so that the writer can furnish no samples for study, but this is doubtless something that comes before the other members of the Society, and although specimens may not be easy to get they can doubtless be found.

PLAN AND SCOPE OF THE PROPOSED INVESTIGATIONS OF STRUCTURAL MATERIALS UNDER THE AUSPICES OF THE UNITED STATES GEOLOGICAL SURVEY.

By J. A. Holmes and Richard L. Humphrey.

The United States Geological Survey for many years has been carrying on investigations of the natural resources of this country. Requests have been coming, with increasing frequency, from engineers throughout the country for information regarding the properties of the materials of construction manufactured from these raw products.

In order to supply the needs and bring the work more directly in touch of the engineer, a new department under the title of technology and metallurgy has been organized, and the first illustration of its operation was in connection with the investigation of Fuels, which was inaugurated during the past year as one of the United States Government Exhibits of the Mines and Metallurgy Department of the Louisiana Purchase Exposition.

It was organized on what might be called a small commercial basis, 250 H.P., for which Congress appropriated on April 28, 1904, and available until June 30, 1905, $60,000, with a proviso that it should be used for analyzing and testing coals and lignites of the United States, to determine the most economical method for their utilization, but stipulating that all the testing machinery and all of the coal and lignites to be tested, should be furnished to the Government free of charge.

Considerable delay in equipping the plant was occasioned by these provisions, as it was necessary to induce a large number of manufacturers to incur the expense of providing the equipment necessary to carry on the work. Labor strikes at some of the factories supplying the equipment occasioned a still further delay, and the plant was not put in operation until September 1st, 1904.

The railroad companies entering St. Louis, or having coal

resources along their lines have cooperated most heartily in these investigations, a preliminary report of which may be obtained upon application to the Director of the United States Geological Survey.

This exhibit and the Collective Portland Cement Exhibit and Model Testing Laboratory of the Association of American Portland Cement Manufacturers, which is fully described in the paper on the subject, by Mr. Richard L. Humphrey, formed two very interesting features of the Exposition. They were working exhibits and accomplished much good in an educational way, besides yielding valuable data relative to fuels and the various building sands and garvels of this country, and were supported with funds available only for the period of the Exposition.

The important results obtained and to be secured through a continuance of the work led to an earnest appeal to Congress on the part of those interested in the work which resulted in a liberal appropriation for the continuance of the investigation of fuels and structural materials on a much more extensive plan. With the appropriation for structural materials which became available in March of the present year, it was decided to confine the work commenced during the Exposition for the present, to the investigation of sands, gravels and broken stone and other constituent materials of mortars and concretes and to the study of mortars and concretes, plain and reinforced with steel.

The equipment of the Model Testing Laboratory has been added to, and in this will be carried on the physical tests of the constituent materials of mortars and concretes and the smaller test pieces made from this material.

The tests of large test pieces, concrete beams, columns, hollow blocks, etc., will be made in what is known as the Metal Pavilion, approximately 59 x 100 ft., having a granolithic pavement covering one-half this area. The equipment of this department will consist of two one-half cubic yard mixing machines, several pneumatic tampers, five hollow block machines, a 200,000 and a 600,000 pound screw beam testing machine, adopted for tension, compression and transverse tests, having a capacity for columns up to 24-ft. length, transverse specimens up to 20-ft. span, and tension specimens 20-ft. long with 25 per cent. elongation, together with the requisite measuring devices.

The chemical and microscopical laboratory occupies commodious quarters in the building used for a model foundry during the Exposition.

This work is under the direction of Mr. Richard L. Humphrey, and will include not only the work in the St. Louis Laboratories, but that carried on under the direction of the Reclamation Service and the investigations at the various technological institutions; the latter in conjunction with the work of the Joint Committee on Concrete and Reinforced Concrete.

The American Society of Civil Engineers about one and one-half years ago appointed a Committee on Concrete and Reinforced Concrete with instructions to affiliate in its work with similar committees of the American Society for Testing Materials, the American Railway Engineering and Maintenance of Way Association and the Association of American Portland Cement Manufacturers.

This Joint Committee appointed a sub-committee on Tests, under whose direction was inuagurated a series of investigations in a number of technological institutions during the last school year. Owing to the insufficiency of funds for this purpose, and also by reason of incomplete inspection, and the untrained character of the students who made the tests, it was not deemed advisable to carry on this work very extensively under such conditions. At a meeting of the Joint Committee at Atlantic City, New Jersey, in June, it was decided to cooperate with the Government in the investigation of Structural Materials, as far as they applied to Concrete and Reinforced Concrete, and the Government agreed to cooperate with the Joint Committee in carrying on such tests and in supervising the work at those technological institutions engaged in these investigations under the direction of the Joint Committee.

The systematic study of fuels from all parts of the United States, which was fairly started at the close of the Exposition, has been continued on a more elaborate scale, especial attention being given to briquetting slack and refuse coal and also to the use of lignites in gas producers. This work alone gives promise of results which will more than justify the money expended.

It has been found that the efficiency of the average bituminous coal is 2½ times greater when used in a gas producer and engine, than when used in the steam boiler and engine.

It has also been found that some lignites, when tested in the gas producer and gas engine, gave unexpectedly high efficiency such as promise large future developments, and further it has been found that some coals and the slack produced in mining these coals can be briquetted on a commercial basis.

These investigations during the Exposition were carried on under the direction of a committee consisting of Dr. Edward W. Parker, Dr. Joseph A. Holmes, and Mr. M. R. Campbell, of the United States Geological Survey; the work is now under the direction of Dr. Joseph A. Holmes.

The investigation of timber (Prof. W. K. Hatt, Asso. M. Soc. C. E., in charge) under the direction of Mr. Gifford Pinchot, is limited at present,—

1. To those species which promise to be on the market for an indefinite period,
2. To actual market products; and
3. To such purely scientific work as forms the basis of correct methods of tests.

The present knowledge of the structural value of the timbers of the United States in the form of large sticks is astonishingly meagre. Such tests as have been made have been made incomplete and defective in many respects. After the present program is carried out there will exist authoritative and complete information concerning the mechanical properties of the commercial timbers of the United States.

This work is being carried on in the laboratories located at present at the University of California, Berkeley, California; Purdue University, Lafayette, Indiana; and the Yale Forest School, New Haven, Connecticut.

One object of the tests is to aid in the forming of definite inspection rules for the various grades of structural timbers. The timber program also includes tests to determine the effect of artificial seasoning, such as is used in the operations preliminary to the preserving processes, and the effect of the presence of the preservatives themselves. This work is under the direction of Dr. H. Von Schrenk, being a continuance of experiments inaugurated during the Exposition in timber treating and testing.

In order that the money, available for the work outlined above, should be expended in such a way as to secure the most efficient

results, it was thought advisable to create an Advisory Board composed of the various National Societies directly interested, to whom could be referred the scope to be covered by the investigations, the methods to be used, and from whom could be obtained a critical opinion of the results. Accordingly, an invitaiton was extended by the Secretary of the Interior, with the endorsement of the Secretary of Agriculture, to the various National Societies, requesting their President, or some other representative, to serve on an Advisory Board for the investigation of fuels and structural materials.

In response to this invitation a meeting was held in Washington, D. C., on June 3, 1905, in the office of the Director of the United States Geological Survey, at which meeting were present:

Dr. Charles B. Dudley, President, American Society for Testing Materials, Chief Chemist, Pennsylvania Railroad.

Mr. C. C. Schneider, President, American Society of Civil Engineers; Chairman, Joint Committee on Concrete and Reinforced Concrete; Consulting Engineer.

Mr. George S. Webster, Chairman, Committee on Uniform Methods of Tests, American Society of Civil Engineers; Chief Engineer City of Philadelphia.

Mr. Richard L. Humphrey, President, National Association of Cement Users; Consulting Engineer.

Mr. Robert W. Lesley, representing the Association of American Portland Cement Manufacturers; President, American Cement Co.

Mr. F. H. Newell, Chief Engineer, Reclamation Service, United States Geological Survey.

Mr. Kort Berle, representing Mr. James K. Taylor, Supervising Architect.

Mr. Gifford Pinchot, Chief Forester, Forestry Service.

Dr. Joseph A. Holmes, Fuel Expert, representing United States Geological Survey.

There were also present by invitation:

Mr. E. A. Foose, representing Mr. J. E. Muhlfeld, General Superintendent of Motive Power, B. & O. R. R.

Mr. E. F. Kenney, representing Mr. Joseph T. Richards, Chief Engineer, M. of W., Pennsylvania R. R.

Mr. A. A. Robinson, Engineer of Bridges, representing Mr. James Dun, Chief Engineer, Santa Fé Ry.

Mr. D. W. Lum, Chief Engineer, Southern Ry.

Mr. W. C. Cushing, Engineer M. of W. Penna. Lines West of Pittsburg.

Mr. C. H. Buckingham, representing Mr. J. F. Deems, General Superintendent of Motive Power, N. Y. C. & H. R. R. R.

Mr. J. E. Greiner, representing Mr. D. D. Carrothers, Chief Engineer, B. & O. R. R.

Mr. W. L. Hall, of the Forestry Service.

The meeting was called to order by Dr. Joseph A. Holmes, who, in the unavoidable absence of the Director of the United States Geological Survey, explained the object and purpose of the meeting.

The Advisory Board organized by the election of Dr. Charles B. Dudley, M. Am. Soc. C. E., President, and Mr. Richard L. Humphrey, M. Am. Soc. C. E., Secretary.

The scope of the investigation of Structural Materials for the present year was considered at length, and the program given in the Appendix was finally adopted.

The following National Societies are represented on the Advisory Board:

American Society of Civil Engineers,
American Society of Mechanical Engineers,
American Society of Electrical Engineers,
American Institute of Mining Engineers,
American Society for Testing Materials,
American Institute of Architects,
American Railway Engineering and Maintenance of Way Association,
American Railway Master Mechanics Association.
Association of American Portland Cement Manufacturers,
Geological Society of America,
National Association of Cement Users,
National Board of Fire Underwriters,
National Fire Protection Association,
National Lumber Manufacturers Association.

There is also associated with this Advisory Board a representative from each of the following branches of the Government:

Bureau of Yards and Docks, U. S. N.,
Corps of Engineers, U. S. A.,
Forestry Service,
Geological Survey,
Isthmian Canal Commission,
Reclamation Service,
Supervising Architect.

The Advisory Board is expected to be a continuous one and will supervise what it is hoped will be an exhaustive series of investigations of fuels and structural materials. The Board will not only pass on the plan and methods for carrying on the work, but will also pass on the advance results of the tests, and the various branches will thus have the benefit of the advice of the foremost engineers of the country.

It is the first time in the history of the United States Government that such extensive cooperation has been effected with outside engineers, although the plan has long been in use in European countries. Such close relations between the users of the materials of construction and the branches of the Government engaged in testing such materials will result, it is believed, in more expeditious and satisfactory work and will prove of great economic advantage to both public and private interests. Heretofore such investigations have been conducted by those in the employ of the producer or consumer at such times and under such conditions as would not seriously interfere with routine work. They were, therefore, necessarily incomplete, and lacked the thoroughness desirable. The present investigations will be conducted by a disinterested and wholly impartial party, possessing the requisite time and money, and the results should therefore prove invaluable.

APPENDIX.

LABORATORIES FOR TESTING STRUCTURAL MATERIALS, UNITED STATES GEOLOGICAL SURVEY, SAINT LOUIS, MO.

Cements, Mortars and Concretes.

Scope of the Investigations to be Conducted During the Fiscal Year Ending June 30th, 1906.

I. *Examination of Constituent Materials.*—Sands, gravels, stone, stone screenings, slags, cinders, etc., to be collected by a special representative of the Testing Laboratory sent out for that purpose.

A. Examination of Deposit

as to the extent and nature of the material from which the samples are collected.

B. Physical Tests in the Laboratory:

1. Mineralogical examination,
2. Specific gravity,
3. Weight per cubic foot,
4. Sifting (granularmetric composition),
5. Percentage of silt and character of same,
6. Percentage of voids,
7. Character of stone as to percentage of absorption, porosity, permeability, compressive strength and behavior under treatment.

C. Chemical Analysis

as to the character of the stone, silt, etc., used in these tests.

II. *Tests of mortars* made with a Typical Portland Cement and sand, gravel and stone screenings. The Typical Portland Cement to be prepared by thoroughly mixing a number of brands, each of which must meet the following requirements:

Specific Gravity—3.10.

Fineness—residue not more than, 8 per cent. on No. 100 and 25 per cent. on No. 200 sieve.

Time of Setting:

Initial set not less than 30 minutes;

Hard set not less than 1 hour or more than 10 hours.

Tensile Strength:

24 hours in moist air ....175 lbs.

7 days (1 day in moist air, 6 days in water) 500 lbs.

28 days (1 day in moist air, 27 days in water) 600 lbs.

One part Cement 3 parts Standard Sand:

7 days (1 day in moist air, 6 days in water) 175 lbs.

28 days (1 day in moist air, 27 days in water) 250 lbs.

Constancy of Volume:

Pats of neat cement 3 inches in diameter ½ inch thick at center, tapering to a thin edge, shall be kept in moist air for a period of 24 hours:

A. A pat is kept in air at normal temperature and observed at intervals for at least 28 days.

B. Another pat is kept in water maintained as near 70 deg. F. as practicable and observed at intervals for at least 28 days.

C. A third pat is exposed in an atmosphere of steam above boiling water in a loosely closed vessel for five hours.

These pats must remain firm and hard and show no signs of distortion, checking, cracking or disintegration.

The cement shall contain not more than 1.75 per cent. anhydrous sulphric acid or more than 4 per cet.n magnesium oxide.

A test of the neat cement must be made with each mortar series for comparison of the quality of the Typical Portland cement.

A. PHYSICAL TESTS IN LABORATORY:

1. Tensile strength with one part cement to varying percentages of material under test for 7, 28, 90, 180 and 360 days;
2. Compressive strength with one part cement to varying percentages of materials under test for 7, 28, 90, 180 and 360 days;

3. Transverse strength with one part cement to varying percentages of material under test for 7, 28, 90, 180 and 360 days;
4. Yield in mortar;
5. Tensile strength with cement, material sieved to one size, 7, 28, 90, 180 and 360 days;
6. Compressive strength with cement, material sieved to one size, 7, 28, 90, 180 and 360 days;
7. Transverse strength with cement, material seived to one size, 7, 28, 90, 180 and 360 days;
8. Porosity.
9. Permeability.

III. *Tests of Concrete* made with stone, stone screenings, gravel, sand, cinder, slags, etc.:

A. PHYSICAL TESTS IN LABORATORY:

1. Tensile strength with different mixtures as to proportion and size of the aggregates, for 30, 90, 180 and 360 days.
2. Compressive strength with different mixtures as to proportion and size of the aggregates for 30, 90, 180 and 360 days;
3. Transverse strength with different mixtures as to proportion and size of aggregates for 30, 90, 180 and 360 days.
4. Absorption.
5. Weight per cubic foot.
6. Modulus of elasticity in compression and tension;
7. Character crushed material used;
   (*a*) Weight per cubic foot.
   (*b*) Size,
   (*c*) Percentage of voids,
   (*d*) Percentage of silt.
8. Porosity;
9. Permeability;
10. Fire resisting qualities;
    (*a*) Effect on hardening concrete.
    (*b*) Effect on hardened concrete
11. Freezing tests;

12. Yield of concrete;
13. Effect of vibration,
    (*a*) On hardening of plain and reinforced concrete.
    (*b*) On hardened plain and reinforced concrete.
14. Protective influence against corrosion of metal;
15. Adhesion of concrete to metal for varying periods, under varying conditions, up to at least 3 years;
    (*a*) Embedded,
    (*b*) On flat surfaces.

B. FULL-SIZE TESTS:

1. Beams of various spans, sections and compositions;
2. Building blocks and bricks as to:
    (*a*) Compressive strength, wet and dry mixtures,
    (*b*) Transverse strength, wet and dry mixtures,
    (*c*) Shearing strength, wet and dry mixtures,
    (*d*) Absorption, wet and dry mixtures,
    (*e*) Permeability,
    (*f*) Methods of waterproofing,
    (*g*) Fire resisting qualities,
    (*h*) Efflorescence.

IV. *Tests of Reinforced Concrete*: *Beams.*

A. PHYSICAL TESTS IN LABORATORY:

1. Varying percentages of round, square and flat bars in bottom,
2. Varying percentages round, square and flat bars in bottom and top.

Approved by the Advisory Board June 3d, 1905.

CHARLES B. DUDLEY, *President.*
RICHARD L. HUMPHREY, *Secretary.*

DISCUSSION.

Mr. Hall. MR. WILLIAM L. HALL.—The Bureau of Forestry stands with the Geological Survey in certain tests along this line. In its work on the preservative treatment of wood, and the testing of structural timbers, the Bureau is dealing with the same problems to which this Society has given its attention.

With its work in the testing of timbers most of you are already acquainted through the report given at the last meeting of this Society by Professor Hatt. The program which he presented to the Society two years ago, and which the Society has printed as a special paper, is being carried out with very little modification. Work will be carried forward from this time in six laboratories located at convenient points. Much attention is also being given by the Bureau to the treatment of wood to make it last as long as possible. There is no doubt but that in wood properly treated the question of decay is practically eliminated. The important problems therefore in this work are:

1. What preservatives shall be applied under given conditions?
2. How are the preservatives to be most efficaciously applied?
3. The question of decay under control—how can timbers best be protected against mechanical wear?

The Bureau will work on these problems by much the same system adopted for its timber tests. It will establish experimental plants wherever necessary on its own account, and in addition will carry on experiments in co-operation with railroads and other companies which operate treating plants.

In connection with its timber tests and preservative treatments, the Bureau will go further and study the properties of different woods which particularly adapt them for special uses. It is just now beginning a study of woods for cooperage purposes, for vehicles and implement manufacture, for box boards and for paving blocks. The study will be extended later to other classes of wood.

Our hope is to reach that point where each of our commercial timbers can be so handled and used that it will give the greatest

service it is capable of giving. In all of this work the Bureau desires to the fullest extent the counsel and co-operation of engineers who are interested in the results. **Mr. Hall.**

MR. GAETANO LANZA.—In this connection it appears to me that it might be of interest to the members of this Society to learn of a piece of information I obtained a short time ago regarding another government department, namely, the Watertown Arsenal. I understand that there is great probability that instead of waiting until the end of the year before publishing the results of the tests made there, bulletins will be issued soon after the tests are made. I should suppose, if such a thing be done, that the bulletins would be distributed to persons especially interested in such tests. **Mr. Lanza.**

MR. R. W. LESLEY.—Referring to the point made by Prof. Lanza, we all know that the Government publishes a great deal of valuable information, and that much of that valuable information is buried. We realize that if this Advisory Board, and laboratory operated under its advice, be backed and sustained by the scientific societies of the country and by the money of the Government, we shall have a means of circulating most valuable information to these people to whom that information will be of use. In other words, while we are all opposed to trusts for money making, I consider this a great big trust for information —information not for one, but for all. I sincerely believe it is the beginning of one of the great institutions of this country—a big engineering experiment station. **Mr. Lesley.**

A LABORATORY COURSE IN TESTING MATERIALS OF CONSTRUCTION.*

By W. Kendrick Hatt.

Prefatory Note.—A laboratory course of practice in the determination of the mechanical and physical properties of materials, commonly called "testing materials," has come to be part of an engineering course, either as a separate course or as part of a course in the general engineering laboratory. The author does not know of any special discussion of the content and method of administration of such a course, and here presents such a discussion with the desire of obtaining criticisms from professional testing engineers. This paper is based upon the course developed in the Laboratory for Testing Materials of Purdue University. The practice of administration of the course as far as the sequence of experiments is concerned is not wholly logical, but is conditioned by the necessity of arranging instruction for large sections of students.

Outline of Work in Laboratory for Testing Materials.

Aims.—The aims of administering the work in the laboratory are as follows:

1. The student is to obtain a knowledge of materials by handling them and watching their behavior under stress. From the appearance before and after test he is led to recognize the nature of normal and defective samples, and the degree of uniformity to be expected. This knowledge will give character to the work of engineering design, and will be of service in work of inspection.

2. A knowledge of the technique of testing materials is gained, by which he may know afterwards if proper methods are being

* The author desires to acknowledge the assistance given by Messrs. E. J. Fermier and E. L. Hancock, Instructors in Applied Mechanics in Purdue University, in the preparation of the above paper.

used in cases that come under his inspection, and by which he may judge the significance of results of the tests of material submitted to him.

3. A training is given in precise methods of observation.

4. The class room instruction in Applied Mechanics is reinforced with concrete knowledge of things and properties, which are otherwise only words defined in text books. The application of theoretical analysis to the tests performed in the laboratory becomes of individual interest and is fixed in the mind. Discrepancies between theoretical deductions and results of tests of actual material as supplied to the market also become evident. Many of the fundamental facts relating to metals, such as the relative stiffness of hard and soft steel, the elevation of the yield point, and the lowering of the elastic limit through overstrain can also be brought to the student's notice by a few well selected experiments.

5. Thesis work in testing materials presents a ready and attractive medium by which students can receive some training in proper methods of planning and executing experimental investigations. The work may be individual, or performed by groups of students, and the expense of material is small. If the professor is interested in some one field of investigation and systematically plans or lays out the field for a term of years, the theses in time are of use in extending knowledge.

Methods of Instruction.—Work is assigned from day to day according to the progress of the student. The laboratory work is self-contained, *i. e.*, the work is all to be performed during the time assigned by the faculty, and the calculations are performed and the reports written up under the eye of the instructor. The students work in parties of three. An outline of the experiment is given to the student before performing the test. The data is taken and the reports are handed in as results. Slide rule calculations are used. From time to time lectures are given explaining the manufacture and properties of the common materials tested, and dealing with the technique of testing.

One valuable feature of the work as administered is that the student is referred to standard text books and standard specifications, and is asked to ascertain how far the material tested deviates from the character of the normal material. At times materials

are given to the student without description or name and he is asked to make tests and determine their commercial rating.

The specifications on hand are: American Society for Testing Materials; Pennsylvania Railroad, and J. I. Case Threshing Machine Company. The volumes in the laboratory are in part: Reports of Tests of Metals, Watertown Arsenal; Materials of Construction, by J. B. Johnson; Masonry Construction, by I. O. Baker; and Handbook of Testing Materials, by A. Martens (translated by Gus Henning).

The method of administering thesis work in general involves the following steps: A list of problems, to which, on account of limitations of equipment and the desire to concentrate, the work of the laboratory should be confined, is prepared early in the year. Theses subjects are generally chosen from this list by students. When a subject is chosen by a student, a thesis outline is prepared by the professor in consultation with the student, in which the problem is clearly stated; the authorities, if any, cited; a list of literature, or directions to main source of information given; and the main plan of attack fairly definitely indicated. Details of apparatus, etc., are generally left to the student. At times a student presents a subject of his own choice. It is thought that it is better that he should be given sufficient guidance and should thus come to the end of the year with some definite conclusions reached, than that his energy should result in a mass of tangled data such as the average undergraduate obtains by his own inexperienced planning. Insistence is placed upon form of presentation and analysis of the subject. The written thesis covers a clear and logical account of the purpose of the thesis; the material tested; the methods and machines, with a discussion of error; the actual results; the analysis and presentation of the results; and the conclusions therefrom. All data remains the property of the University, and publication of the results may only be made by the student with the consent of the University authorities.

MACHINES AND APPARATUS.

The equipment in a testing laboratory in a State University is primarily for routine instruction and incidentally for research and for assistance to the various technical interests of the State or

the general public. This equipment should include a preponderance of small machines suitable for routine experiments. The author has found a 30,000-pound universal knife-edge-lever machine best suited for this purpose. It should be operated by power and spur gearing. The poise should be a dial poise. Naturally, in this country the choice will be between the Olsen and Riehle type of machine. The speeds should be as follows:

Up and down fast speed for adjusting $2\frac{1}{2}$ inches per minute.
Down for flexure .15 inches per minute.
Down for extensometer tests 1-100 inch per minute.
Distance between screws 8 inches.
Clear travel of heads 22 inches.

It will be of no particular advantage to have this machine automatic or autographic.

Flexure tests are provided for by placing a small "I" beam across the platform of the testing machine. The machine should be calibrated either by special levers or else according to the practice of the author, by the use of a standard nickel-steel bar whose modulus of elasticity is measured with a calibrated extensometer. The bar is kept in the laboratory and is not strained beyond its elastic limit. In three instances in the author's experience this calibration has been found necessary. A nut on the bed of the machine calibrated had worked loose and through lack of clearance had blocked the main lever at a load on the testing machine of one-half its capacity.

For the work of thesis investigation and tests for outside parties machines of large capacity are needed. Such a machine serves for tests on columns, girders, couplers, draft rigging and miscellaneous railway appliances, reinforced concrete beams and "I" beams. Such a machine should have vertical head room of at least 10 feet, and a distance between screws of 26 inches.

A cross table for flexure is not necessary and may be provided for by an "I" beam. The futility of providing a cross table designed for the full capacity of the testing machine, as is sometimes the case, is evident.

The capacity of the large machine is a matter needing discussion. The author would provide for a 200,000-pound machine, and then jump to one of large capacity—over 600,000 pounds. A machine of the latter type need not be a knife-edge machine.

It is only useful for testing manufactured articles or large structures in which there is a great inherent variability. A machine whose accuracy is in keeping with such material may be of the hydraulic type. The load may be measured upon a diaphragm gauge. A horizontal machine seems the most convenient. A machine may be calibrated from time to time by the use of a large nickel steel bar with extensometers. This will check up any great variation in friction in the packing of the piston.

A torsion machine should be provided to illustrate the laws of torsion. A 60,000-inch pound machine will be sufficient.

Some form of impact machine serves well to illustrate the phenomena of rupture under impact, and the mechanical relations between work and energy. A convenient form of machine is the one recently built by Purdue University for the Bureau of Forestry providing for compression and flexure impact tests. The hammer varies from 50 to 250 pounds. The fall is 6 feet. The base is 7 feet long. Total weight of machine is about 4,000 pounds. The hammer is lifted by an electric motor through the medium of an electric magnet. A gentle and convenient release is brought about by cutting the current off from this electric magnet. There is a pencil attached to the hammer which writes a curve on a revolving drum, whose speed is shown by the record of the tuning fork thereon.

Further apparatus will naturally be governed by the individual interests of the professor in charge, and the interests of the State which the laboratory serves. There is no need of providing certain special apparatus in all laboratories any more than there is need for duplication of highly specialized courses of instruction in some particular branch of technology in two universities near at hand to each other.

Extensometers.—The commonly used, electric contact extensometer reading to 1-10,000 of an inch, teaches care of manipulation, but the deformations at the elastic limit and yield point are not evident to the senses as they are in a roller extensometer. The author has found the Johnson extensometer most favorable to the work of instruction and research. He has not found it possible is his laboratory to use the mirror extensometer on account of the jarring of the machinery resulting from the general work of the laboratory.

A compressometer reading to $\frac{1}{10000}$ inch is highly useful in determining the fundamental properties of brittle materials, and a number of deflectometers reading to 1-100 of an inch are useful for flexure tests.

The Henning Recorder is a very useful apparatus from an educational standpoint. The rupture-work and the relations of the various constants of the material are brought distinctly to the notice of the students.

The usual micrometers and scales need not be described. A note may be made concerning the usefulness of plaster of Paris in testing concrete or stone specimens.

A drying oven is often needed to determine the moisture in wood, or to dry out bricks before testing. Some form of abrasion machine is useful in preparing stone specimens for compression tests.

The standard equipment of a cement testing laboratory should be included. The automatic shot machine is no doubt the best type of these machines; a type in which the load is applied through the flow of shot from the bucket has proved satisfactory to the author. Mechanical mixers, molders and tampers are of a doubtful value.

As indicative of the growth of the equipment of a laboratory, the following list is given of the machines in the Laboratory for Testing Materials of Purdue University:

1 300,000-pound Universal Riehle Testing Machine capable of testing specimens in compression up to 10 feet in length. This machine is used for testing concrete beams, draft rigging, car bolsters, and large work.

1 200,000-pound Riehle Testing Machine, autographic and automatic.

1 100,000-pound Olsen Universal Testing Machine.

1 50,000-pound Riehle Hydraulic Testing Machine.

1 30,000-pound Falkenau-Sinclair Universal Testing Machine.

3 30,000-pound Olsen Universal Testing Machine.

1 Impact Testing Machine for compression and tension with a drum for automatic records, and mechanical hoist. 500- and 800-pound hammers, o feet free fall in compression.

1 Impact Testing Machine for compression and flexure tests, electric magnet hoist and release. 50-, 100- and 250-pound hammers, 6 feet free fall.
1 Impact Testing Machine for car axles and couplers with a 2,000-pound hammer and height of 50 feet. Deposited by the Master Car Builders' Association.
1 Abrasion Testing Machine (deposited), Dorry type.
1 Rattler for testing paving blocks, Purdue type.
1 Riehle Wire Tester of 600 pounds capacity, with spring dial.
1 Flexure Machine for testing cast iron. (Deposited.)
1 2,000-pound Olsen Cement Testing Machine.
1 1,000-pound Fairbanks Automatic Shot Cement Testing Machine.
1 1,000-pound Falkenau-Sinclair Automatic Shot Cement Testing Machine.
1 60,000-pound Olsen Torsion Testing Machine.
1 60,000-pound Riehle-Miller Torsion Testing Machine. (Deposited.)

The cabinet of the laboratory contains a good collection of scales, micrometers, and instruments of precision.

1 Riehle-Yale Extensometer.
2 Johnson Dial Extensometers, with auxiliary yokes for compression tests of concrete cylinders.
1 Olsen Lever Extensometer.
1 Olsen Compressometer.
1 Henning Pocket Recorder.

TIME DEVOTED TO WORK.

Electrical and mechanical engineers report one period of two hours per week for one semester.

Civil engineers report one period of two hours per week for two semesters.

EXPERIMENTS.

A list of experiments from which assignments are made in the author's laboratory is as follows:

1. Commercial Tension Test on Iron and Steel. (Without proportional limit or modulus of elasticity.)

2. Henning Recorder, Iron and Steel.
3. Yale Extensometer, Iron and Steel. (Proportional limit and modulus of elasticity.)
4. Johnson Extensometer, Iron and Steel.
5. Compression Test and Flexure Test of Stone and Brick.
6. Compression Test on Wood.
7. Compression Test on Iron and Steel.
8. Compression Test on Concrete, using compressometer.
9. Flexure Test of Wood Sticks.
10. Flexure Test of built structures like Brakebeams or Bolsters.
11. Flexure Test of Concrete and Reinforced Concrete.
12. Torsion Test of Steel.
13. Impact Tests.
14. Cement Tests.
15. Specific Gravity of Cement.
16. Wire Rope Test—Test of Separate Wires.
17. Wire Rope Test—Entire Rope.
18. Cloth and Yarn Test.
19. Belt Testing.
20. Cold and Quench Bending Test.
21. Hard and Soft Steel Flexural Test.
22. Effect of Overstrain and Subsequent Annealing.
23. Rattler Test for Brick.
24. Analysis of Data.
25. Test of Draft Rigging.
26. Test of Couplers.
27. Calibration.

FORMS AND INSTRUCTIONS.

It is recognized that instruction in a laboratory for testing materials demands a more constant supervision and closer attention on the part of the instructor than is the case in, for instance, a steam laboratory, since the operations of placing material in the machine and attaching micrometers differ with nearly every experiment. Furthermore, the attention of the student should be called to the phenomena which occur in the material under test. Due to necessity, however, of organizing the work for the handling of large

sections, it is necessary, as far as possible, to prepare forms directing the operations of the student and instructing him with reference to the preparation of the reports.

Such reports in general should state the purpose of the experiment, the material supplied, the methods of tests, a presentation of the actual data, analysis and exhibition of the data in the form of diagrams, and finally the conclusion, or comparison of the results with standard results. It is not the author's belief that the student's time is profitably used in making elaborate drawings of machines and apparatus used, and it is his practice to do away as far as possible with merely clerical work on the part of students by supplying the proper forms.

There is here appended a number of directions for performing the more important experiments in the laboratory. Such instructions are supplied to students in their work. These are offered with the hope that they may prove of use to other instructors, and with the desire to obtain criticism upon the methods therein outlined. The forms are not complete for all the experiments, but the main experiments are included.

TENSION TEST OF IRON AND STEEL.

I. *Purpose of the Experiment.*

The experiment is intended to represent the conditions obtaining in an ordinary commercial test with the exception that the speed of descent of the pulling head of the testing machine is much slower than customary in commercial laboratories. The experiment will determine the strength and ductility of the material which are the common measures of quality. The kind and classification of the material supplied may be known from the results of the experiment.

II. *Preliminary.*

1. Note the serial number or mark on the specimen.

2. With vernier or micrometer calipers measure the average dimensions of the cross section.

3. Lay off gauge length of eight inches, each inch being marked by a light center punch mark.

4. Carefully balance the testing machine and then insert the test-piece in the wedges, being careful that the test-piece is cen-

trally disposed in the axis of the machine, and that the ends of the test bar project slightly beyond the wedges. Grip the wedges by applying a load of about 500 pounds. Chalk a small area of the bar near the upper gauge mark. Before proceeding with the test allow the instructor to inspect the work.

III. *Operations in Testing.*

One student should insert one leg of a pair of dividers in the lower gauge mark and scribe a line with the upper leg on the area previously chalked. Apply the load at a low and uniform speed and operate the poise so as to keep the scale beam floating.

The operator with the dividers should notify the operator at the poise when the width of the scribed line increases perceptibly due to sudden increase in the rate of stretching of the test bar under the load. At this time the beam may be expected to drop suddenly and remain down. This increase in elongation without a corresponding increase in loads is the "Yield Point," or commercially, the "Elastic Limit." It is a point beyond the true elastic limit as obtained in experiment No. 3.

During a further stretching of the bar the beam will again rise and should be kept floating up to the maximum load. At this maximum load the bar begins to neck in, the material becoming plastic at the point of the formation of the neck. Record in the report the yield point and the maximum load.

IV. *Measurements after Tests.*

Lay the broken ends of the bar together and determine the increase in elongation of the gauge length. Measure the dimensions of the fractured area. Determine the rate of descent of the pulling head of the machine. Describe the appearance of the fracture and determine the distance from the extreme gauge point.

V. *Calculations.*

Calculate the ultimate strength.

$$\text{Ultimate strength} = \frac{\text{maximum load}}{\text{original area}}$$

Calculate the yield point.

$$\text{Yield point} = \frac{\text{load at the yield point}}{\text{original area}}$$

Calculate the per cent. of elongation and per cent. of contraction of area.

$$\text{Per cent. contraction of area} = \frac{\text{original area—area of neck}}{\text{original area}} \times 100$$

By reference to various specifications on file in the laboratory determine the kind and classification of the material in the specimen.

In case the fracture is outside the middle third of the gauge-length, the per cent. of elongation is to be computed on the assumption that the elongation is symmetrical on each side of the neck. This should be noted on the report.

VI. *Report.*

Report consists in filling out the blank form supplied for the test (except as indicated by the instructor).

TENSION TEST WITH HENNING POCKET RECORDER.

Object.—To determine the properties of material from load-elongation diagram drawn by apparatus.

Preparation.—Ascertain magnification of the lever in the apparatus. Set the lever stop with a clearance of 0.03 inches. Measure and lay off specimen as for a regular tension experiment. Place the test bar in the wedges of the machine and adjust the apparatus under the direction of the instructor. Wedges must be blocked to prevent their flying out upon rupture of the specimen.

Experiment.—Run out the poise by steps of 4,000 pounds and allow the apparatus to draw a scale of loads on the card up to 50,000 pounds. Apply the load with the intermediate speed, keeping the beam floating until the specimen is broken. Note the load in pounds at the yield limit and the maximum limit.

Computation.—The card is completed by drawing the elongation axis through the zero of loads and at right angles to the load axis, and also a straight line from the rupture point perpendicular to the elongation axis.

The load at yield limit and maximum limit are scaled from the card and checked by observations taken during the test. The per cent. of elongation obtained by the measurements on the fractured specimen is to be checked by scaling from the card. The work of deformation up to any point may be obtained from the area in square inches under the curve up to the point in question by multiplying this area by the scale value in inch-pounds of each square inch of card. This product divided by the volume of the specimen between the gauge points will be the "rupture-work" in inch-pounds per cubic inch.

Compare the value of resilience by the card with the values as obtained from the following formulæ:

$$\text{Elastic Resilience} = \frac{T''^2}{2E}$$

$$\text{Rupture-work} = \frac{\text{per cent. elongation}\,(T'' + 2T')}{300}$$

Where T'' and T' equal the stress in pounds per square inch at elastic limit and maximum load respectively, and E is the modulus of elasticity. E cannot generally be accurately determined from the card. (See instructor for assumed value.)

N. B.—Be sure to record on the data sheet the serial number of the specimen before placing it in the wedges of the machine. Make sure that the magnification of the lever is taken account of in all measurements involving this magnification. The beam must be kept floating throughout the experiment even after the maximum load has been reached.

TENSION TEST WITH EXTENSOMETER.

Object.—In this experiment the elastic properties of metals in tension are determined.

Method.—Carefully measure and prepare each specimen as for regular tension test (note the serial number on the specimen). Grip the piece in the wedges by applying a load of about 100 pounds (the machine having been previously balanced). Apply and adjust the extensometer, and (*after having had the apparatus inspected by the instructor*) proceed with the test. Apply load in increments of ——— pounds per square inch (an increment

sufficient to produce fifteen measurements of extension up to the elastic limit) and measure the total elongation at each load increment.

After reaching a sudden and large increase in elongation, remove the extensometer and apply load until specimen is ruptured. Note the maximum load.

Computations.—Construct a diagram with load in pounds per square inch as ordinates and elongation in inches per inch as abscissæ. Draw a *straight* line averaging the points up to the more rapid increase in elongation, and, tangent to the straight line, draw a smooth curve averaging the remaining points. Ordinarily, the straight line of plotted points will not pass through the origin. Draw through the origin a line parallel to the straight line of plotted points. This line represents the true relation between stress and strain. Mark the elastic limit x on the two straight lines at the value of the ordinate at the point of tangency between the straight line of plotted points and the smooth curve.

The modulus of elasticity is the stress in pounds per square inch divided by the elongation in inches per inch at any point on the straight line through the origin. It is most convenient to select an abscissa of elongation of one part in 1,000, and multiply the corresponding stress by 1,000 to obtain the modulus of elasticity.

The modulus of elastic resilience is the amount of work done on each cubic inch of the specimen in deforming it to the elastic limit. It may be taken as the area (in inch-pounds) under the straight line up to elastic limit; or it may be calculated by the formula $\frac{1}{2}T'' e''$ where T'' and e'' are the stress and relative elongation respectively at the elastic limit, and must be measured on the line passing through the origin.

Per cent. of elongation and of reduction of area are determined as in the simple tension test.

Report.—The report will consist of (1) tension test blanks (furnished by instructor) properly filled out, (2) plotted curves with titles and scales shown, (3) ink copies of running log.

Mention the form of extensometer used.

Notes.—The extensometers are delicate instruments and must be handled carefully. Any roughness of usage or lack of delicacy in manipulation will result in unsatisfactory diagrams. Be sure that the test bar is straight.

COMPRESSION TEST OF VARIOUS MATERIALS.

The purposes of this experiment are: To obtain knowledge of the proper methods of testing materials in compression; of the crushing strength of such materials; and of the characteristic forms of fracture.

Preliminary.—(1) Before testing any specimen carefully measure its height and cross section.

(2) When brick, stone, concrete, or cement specimens are to be tested they should be carefully bedded either with blotting paper or with plaster of Paris. To bed a specimen with plaster of Paris, have the testing machine balanced, and the head down so far that it will clear the specimen only about one inch or two. Then mix up some plaster of Paris and water to a very thick, creamy consistency. Spread a thin layer of this on paper placed upon the spherical bearing of the machine and cover it with a piece of tough sized paper, upon which the specimen should then be placed. The paper is to keep the water of the plaster out of the specimen. Upon another similar piece of paper a similar pad of the plaster should be spread covered with another piece of paper to form a pad, and the pad then placed upon the specimen. The head of the machine should then be run down rapidly until it presses upon the plaster sufficiently to cause it to flow, thus insuring a good bedding. With the trowels now fill up all the open spaces about the edges of the specimen near the faces of the machine. After letting the plaster set ten or twelve minutes, the specimen is ready to be compressed. The spherical bearing should also be used. Have the work inspected by the instructor before proceeding.

In the case of other materials see that the ends of the specimen admit of a good even bearing in the machine.

The Test.—Using the slowest speed available, now compress the specimen, meanwhile keeping the scale beam floating; and watch carefully the behavior of the specimen.

Computation.—Compute the stress in pounds per square inch at first crack, and at maximum load.

Report.—Report should cover:

Description of material.	Method of test.
Size of material.	Results.

Results.—Load and crushing strength at first crack and at maximum load or failure. Sketch form of fracture.

Comparison of results with standard values. (See instructor.)

COMPRESSION OF MATERIALS.

(*Using Compressometer.*)

(*See also instructions 6a.*)

Object.—In addition to determining the maximum strength in compression, as in other compression tests, it is intended in this experiment to find the strength at elastic limit, the modulus of elasticity, the modulus of elastic resilience and total rupture-work.

Operations in Testing.—Proceed as in other compression tests except that the load is applied in increments of——— pounds (about 1-20 the probable maximum load) and the total amount of compression at each increment is measured by a compressometer. (Use slowest speed of the machine.)

Computations.—Plot points with load in pounds for ordinates and compression in inches for abscissæ. *If possible draw a straight line* averaging the points preceding the more rapid compression; and, tangent to this straight line, draw a smooth curve averaging the remaining points. (Consult instructor before inking in these lines.) Mark the points of maximum load and (which latter is the point of tangency of the straight line and the elastic limit smooth curve) by x. Then draw a line through the origin parallel to the straight line previously drawn through the plotted points. (Do not continue this line parallel to plotted curve.) Mark the point of elastic limit on the corrected line.

The modulus of elasticity is calculated from the formula $E = \frac{Pl}{F\lambda}$ where P and λ are the load in pounds and compression in inches respectively, for any point on the corrected line; F is the square inches of cross-sectional area of the specimen, and l is the gauge-length in inches of the specimen.

The moduli of elastic resilience and the rupture-work are the work done on each cubic inch of material in deforming it up to the elastic limit and ultimate strength respectively. These moduli may be obtained from the curve of plotted points by multiplying the area under the curve (up to the point considered) by the scale

value of each unit area of the coordinate paper, and dividing the result by the volume of the specimen. This will be the modulus of elastic resilience or the rupture-work.

Report.—The report will contain (1) a brief and clear statement of the kind and condition of materials tested, (2) the methods of applying the loads and measuring deformations, (3) any peculiarity in the behavior of the specimen, and (4) a comparison of the properties of the material as obtained from the test with values recorded in reference books, etc. The character and form of fracture should be described and also shown by sketch.

The report will also contain a tabulation of results.

FLEXURE OF WOODEN BEAMS.

The purpose of the experiment are:

(1) To obtain knowledge of strength and method of failure of materials.

(2) A comparison of results with theoretical laws of flexure.

(3) Practice in computing strength of beams.

Preliminary.—Material will consist of three sticks of wood: (a) 2 x 2 x 36 inches; (b) 2 x 4 x 36 inches; (c) 2 x 2 x 18 inches.

(1) Note the serial numbers or marks on each specimen.

(2) Measure and weigh each specimen and count the number of annual rings per radial inch.

(3) Make sketches showing end views with direction of annual rings, sap and heart wood. Note any defects such as knots, season checks, crooked grain, rot, etc.

(4) Mark center lines and span lengths.

(5) Place the beam upon the knife edges, using steel strips to prevent knife edges from crushing the wood, and rollers to prevent chain action. Balance the machine and apply a small initial load and place a deflectometer under the center of the beam, or else hang a special deflectometer on pins in the neutral axis over the knife edges. For a considerable deflection a wire stretched between these pins and a scale attached to the beam at center will suffice. Bring wire to coincide with its image in scale to avoid parallax.

The Test.—Compute the probable breaking load and apply

this in about twenty increments and read the total deflection at each increment. If care is exercised in keeping the beam balanced near point of failure, it will be possible to get the correct load and deflection for failure even though this does not take place at one of the regular load increments. Note the nature of the failure of the beam and sketch the failure.

Working up the Data.—(1) On section paper plot points using load in pounds for ordinates and deflection in inches for abscissæ. Use a separate sheet for each curve. Choose scales such that the slope of the diagram near the origin shall be about 60 degrees. Each division of the paper must represent a decimal increment. Plot each point plainly. Draw a straight line averaging those points which precede the more rapid increase in deflection. Tangent to this line draw a smooth curve averaging the subsequent points. Mark on the curve the elastic limit and the load at failure, *i.e.*, the maximum load. If the straight part of the curve does not pass through the origin, draw through the origin a dotted line parallel to the first. This line will represent the relation between the load and corrected deflection.

(2) Compute (*a*) the modulus of elasticity E by use of formula 4, page 254, Church's Mechanics of Engineering, (d and P are taken from any point on the corrected line). (*b*) R″, the fiber stress at elastic limit. (*c*) R, the fiber stress at rupture. (*d*) U″, the modulus of elastic resilience. (*e*) U, the modulus of total resilience. To compute the modulus of resilience at elastic limit or rupture, divide the inch pounds of work done upon the beam up to that point by the volume in cubic inches of the part between the supporting knife edges. Also find the values of the exponents x, y, z and w in the following equations

$$\frac{P''}{P''_{\prime}} = \left(\frac{h}{h_{\prime}}\right)^x \quad \text{Beams of equal length.}$$

$$\frac{P''}{P''_{\prime}} = \left(\frac{l_{\prime}}{l}\right)^y \quad \text{Beams of equal depth.}$$

$$\frac{d}{d_{\prime}} = \left(\frac{h_{\prime}}{h}\right)^z \quad \text{For equal loads and equal lengths.}$$

$$\frac{d}{d_{\prime}} = \left(\frac{l}{l_{\prime}}\right)^w \quad \text{For equal loads and equal depths.}$$

$P''_{\prime}$ and P'' are loads at elastic limit.

d and d must not be taken beyond the elastic limit, and must be taken from line of corrected deflections.

Compute the weight per cubic foot and the specific gravity, assuming that the per cent. of moisture on the basis of dry weight is 12 per cent.

The Report.—Give a brief description of the method of conducting the experiment. On following pages present the measurements, etc., of the beams; the sketches of cross sections and fractures; the data obtained; the diagrams, and then the computed results in tabular form.

EXPERIMENTS IN TORSION.

Object.—The object of this experiment is to study the behavior of materials under torsion, and to obtain such data as will enable the shearing strength of the material and its modulus of elasticity in shear to be computed.

Material.—The material is to be supplied by the instructor, and may be steel, iron or wood, or other material.

Preliminary.—Carefully measure the dimensions of the cross section and the gauge length. Then adjust the specimen in the heads of the machine, being careful to have the jaws clamped tightly against the specimen, which should be fixed in the axis of rotation of the machine. Then apply the torsion troptometer to the specimen and adjust the clamps of the latter so that the center of the circle of the graduated arc will be in the axis of the machine. Apply a small initial moment of about 100 inch pounds and set to zero the graduated arc, and also the permanent scale on the twisting head of the machine.

Experiment.—Apply the loads continuously in increments of ——— inch pounds. Read on the graduated arc the movement of the pointer in inches for each increment. When the increase in the angle of torsion is found to be rapid, the elastic limit having been reached, the graduated arc and index should be removed.

If only the elastic properties of materials are to be determined the specimen may be removed. Ordinarily the tests are to be continued until the specimen is ruptured. The whole angle of the twist is read from the fixed scale on the movable head of the machine and should be read for even loads above the elastic limit.

The scale should be kept balanced and the maximum load determined.

Computations.—Plot diagrams to suitable scales with the twisting moment in inch-pounds as ordinates and the angle of twist in degress as abscissa. One of these curves will be drawn with the magnified abscissa and will show the points up to the elastic limit. The other curves will be on a small scale and will show the angle-moment diagram up to the rupture. As in other experiments, the straight line portion in the beginning should pass through the origin. If it does not, a straight line parallel to the straight line passing through the plotted points should be drawn through the origin and terminating at the elastic limit.

Mark the points corresponding to the elastic limit and maximum load on the curve. Compute (1) the shearing strength developed at the elastic l'mit and the maximum load, using formula

$$Pa = \frac{Es\ Ip}{e}$$

Calculate the modulus of elasticity in shear from the formula

$$Pa = \frac{aPs\ Ip}{l}*$$

Using the coordinates of any point on the corrected curve of the magnified scale.

Compute also the modulus of elastic resilience and the modulus of total resilience.

Report.—The report will contan (1) a brief description of the specimen and method of test, (2) a tabulated statement of the computed and observed results (rule a form to suit the requirements), (3) a description of the fractured specimen, (4) plotted curves on coordinate paper, (5) an ink copy of the running log of loads and deformation.

INSTRUCTIONS FOR TESTING CEMENT.

(*Short Course.*)

The work will include two days in the Laboratory, and during this time the student will determine the time of setting, the fineness of No. 50 and No. 80 sieve, and the strength of 3 to 1 mortar in the case of standard brands of Portland Cement.

*See Church's Mechanics of Engineering.

Time of Setting.—Mix up neat cement with enough water to render a paste of such consistency that when placed on a glass plate it will retain its form, and at the same time by striking the glass against the hand the paste can be spread out without cracking on the surface.

Trowel the paste on the glass to thin edges, and set the pad thus made aside in a damp chamber, and observe the time that elapses until (1) it will bear the quarter pound standard needle without appreciable indentation; (2), the weight of the one pound standard needle without appreciable indentation.

Tests for Strength.—Mix up the mortar consisting of three parts standard crushed quartz stone and one part Portland cement, proportion being taken by weight. Mix the sand and cement thoroughly until the mixture presents a uniform color. Gauge with about 8 per cent. of water and work over the mixture thoroughly about six times. Tamp in molds in layers, and finish the surface of the briquette. Record the initials on one corner of the briquettes, and leave the briquettes in the molds. They will be taken therefrom by the instructor and placed under water after twenty-four hours.

SECOND DAY'S WORK.

At the laboratory period one week following the briquettes are to be taken from the water and tested for strength.

Tests for Fineness of Grinding.—Sift about four ounces of cement through No. 100 and No. 80 sieve and weigh the residue left on the sieves.

The Report.—Each student should report the results of the tests made by him as an individual to determine the fineness of grinding, the time of setting, and the strength of the five briquettes. Reports should be made on blank forms provided for that purpose.

Special instructions are issued to civil engineers.

Note: The joint discussion of this paper and the succeeding one on "An Elementary Course in Properties of Materials," by G. L. Christensen, follows on pp. 270–276.

AN ELEMENTARY COURSE IN PROPERTIES OF MATERIALS.

By G. L. Christensen.

Instruction in the properties of engineering materials should have the following objects in view:

1. To illustrate the behavior of materials under stress.

2. To establish clear and definite conceptions as to the meaning of such fundamental terms, as elastic limit, yield point, ultimate strength, percentage of elongation, modulus of elasticity, resilience.

3. To familiarize the student as far as possible with the methods by which materials are tested to obtain numerical resul s indicating their qualities.

4. To fix in the memory a *few* of the average numerical values for the more common materials such as cast iron, wrought iron, steel, timber, stone, and concrete; thus establishing a very convenient mental standard of reference for the more detailed study of these and kindred materials, and at the same time forming the basis for that ready judgment so essential to the engineer.

5. To illustrate the use of these numerical values in simple problems of designing, thus associating and connecting the material itself, and the mathematical considerations involved, and laying the foundation for that habit of thought which must ever recognize the material, in its various strengths and elasticities, in every problem of design.

6. To study the processes of manufacture, in so far as these give name to the product or modify its qualities.

7. To study methods of protecting and preserving materials under conditions of use.

The class-room instruction should be fundamental, keeping before the student the underlying principles and truths, and guiding him through the maze of experimental facts to habits of clear, discerning, independent thought; the laboratory, a means of illustration, going hand in hand with the class-room, supplementing,

reviewing, clearing up, fixing the ideas. It is the purpose of this paper to outline briefly some features of the instruction in this subject as developed at the Michigan College of Mines under the increasing influence of this idea of using the laboratory as a means of illustration in conjunction with the class-room work. The course as given runs through twenty-three weeks, three recitations of fifty-five minutes each per week. The text-book is Johnson's "The Materials of Construction." The class, numbering sixty students, is divided into three sections of twenty each for recitations, and each of these sections is again divided into two laboratory divisions of ten students each, making in all six laboratory divisions. During a portion of the course, the first recitation period of each week is set aside for laboratory illustration work, when,

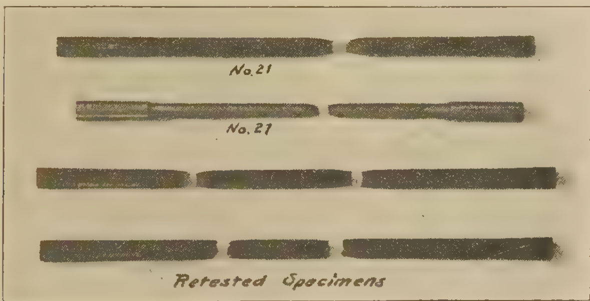


FIG. 1.

instead of the whole section meeting in the class-room, one of the small laboratory divisions of ten students meets in the laboratory, the other division taking some other hour of the same day. With this organization of the class it is possible to undertake a series of tests, the whole class being made familiar with the plan and scope, but each laboratory division doing only a small part of the work.

Beginning the course, the first week is devoted to a class-room consideration of definition of terms and the behavior of materials under tensile stress. In the laboratory period of the second week, tensile tests are made of two specimens both cut from the same wrought iron or mild steel bar, one being rough, one inch in diameter, and the other turned down to a smaller size (Fig. 1). The group of ten students gathers around the testing machine—there is room enough for all to note everything that takes place—and each

student is required to keep full records just as though he were making the test individually. This being the first test, the construction and operation of the testing machine is explained. The rough bar is tested first. It is marked off in the presence of the class, with punch marks an inch apart, and placed in the machine. As the test proceeds, attention is first directed to the detection of the yield point by noting the drop of the beam, then the breaking-down action is watched as shown by the loosening of the mill scale, then interest centers in the rapid stretching of the bar, readily noted

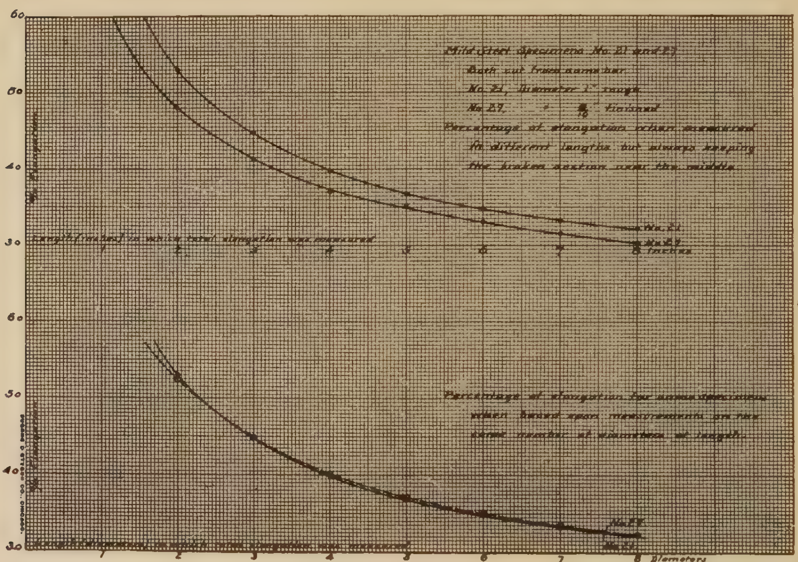


FIG. 2.

with a pair of dividers, and finally, in turn, the ultimate load, the necking down action, and the breaking load are noted. The broken specimen is passed around, it is handled and examined. They note that it is warm. They see the form of fracture and compare it with that of specimens pictured in the text-book. The diameter of the broken section is measured, and, finally, the broken ends are placed together and the elongation in lengths of 2, 3, 4, 5, 6, 7, and 8 inches is measured with a pair of dividers, always keeping the broken section as near the middle of the measured length as possible. The test of the other specimen is then run

through rapidly noting all the results the same as for the first. A neatly-written report of these tests with computed significant results, and a diagram (Fig. 2), showing the variation in percentage of elongaton when based upon different lengths, is required as a part of the next lesson; and the broken specimens find a place upon the class-room table where they remain within easy reach, to be appealed to most effectively, in many a class-room discussion in the weeks to come. These simple tests, readily carried out within the limits of the hour, have kept the little group of students keen with interest, have thrown new light upon many points discussed in the text, have appealed to the eye, the ear, and the sense of touch as no amount of class-room discussion could;

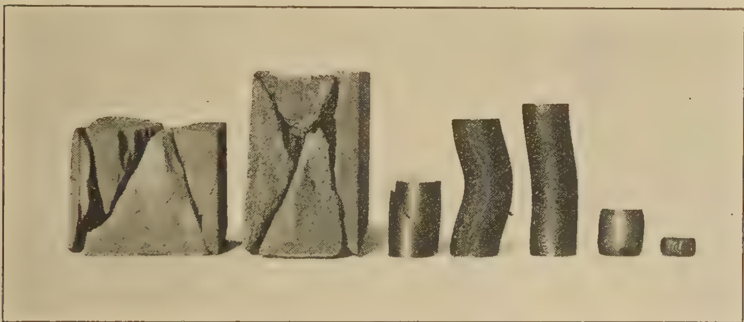


FIG. 3.

and, finally, have added a little of that time element often necessary to the full comprehension of a new subject.

The third week finds the class considering the behavior of materials under compressive stress. Accordingly, the laboratory period is devoted to tests in compression of wrought iron and mild steel, as types of ductile materials, and sand stone, sand-lime brick, and cast iron as types of brittle materials (Fig. 3). The wrought iron and mild steel specimens are cut from the same bars as the tensile specimens (Fig. 1) tested the previous week, thus enabling a comparison of the yield points in tension and compression

After this preliminary study of definitions, principles, and materials, the class is ready for the more specific consideration of each material by itself. It must not be forgotten in this connec-

tion, that nearly all our computations regarding stresses in materials, are based upon the principles of elasticity with stresses

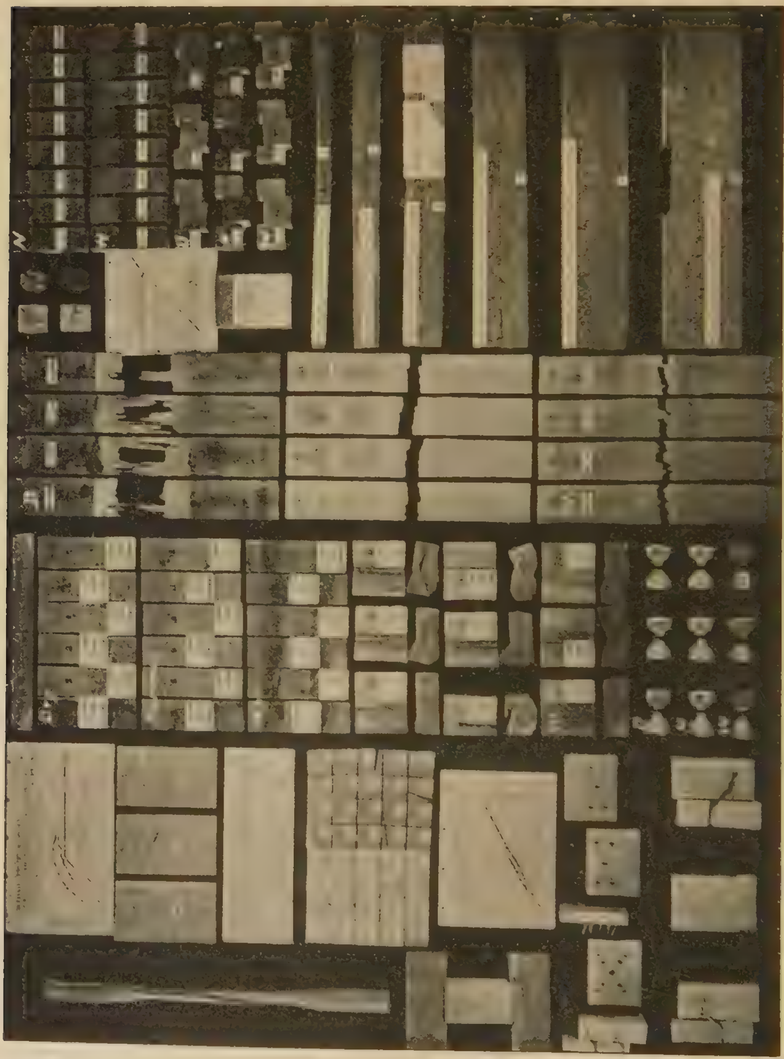


FIG. 4.

below the elastic limit. It is not sufficient, then, to consider only ultimate strengths. The elastic limit, and the more or less perfect

elasticity of the material, as well as its behavior throughout the whole range of stress, should be made the subject of careful study. The student needs to be brought face to face with these principles and qualities, again and again, until they become a part of his unconscious possession, guiding his judgment, giving form to his expression.

Timber seems to offer many advantages as the material first to be considered. It is one of the most common materials of construction. The specimens are easily prepared and cheap. The deformations under stress are relatively great, and, therefore, readily measured. The strengths and elasticities vary in different directions with reference to the grain, thus requiring fuller investigation as well as clear ideas as to direction of stress. The strengths are subject to many variables, and yet, by controlling these variables, or by recognizing their presence, consistent and highly instructive results may be obtained.

Beginning the subject of timber, the first laboratory period is devoted to the examination of the minute structure of wood as revealed by the microscope in transverse, radial, and tangential sections of the common hardwoods and softwoods; this being the basis for explaining so many of its strength, grain, and shrinkage properties. For the strength tests, a clear, straight-grained, well-seasoned, white pine plank, 16 inches broad, and $1\frac{5}{8}$ inches thick, having a little sap-wood in two outer corners, was used (Fig. 4). Specimens from this plank were tested under three conditions of moisture, viz.: "Dry," specimens dried over a boiler one week; "Normal," specimens tested as cut from the plank; and "Wet," specimens kept under water one week. There being six laboratory divisions, the plank was cut so as to give six endwise compression specimens in its width (Fig. 4). Thus, specimens No. 1 Dry, No. 7 Normal, and No. 13 Wet, representing the three moisture conditions, and all from similar positions with respect to the center of the tree, were tested in the first laboratory division (Fig. 5). The next three specimens, in the second division (Fig. 6), and so on (Figs. 7, 8, 9 and 10). These three tests, with full data as to loads and shortenings, were easily finished within the hour. The shortening was measured with a Brown and Sharpe test indicator as shown in Fig 11. This instrument reads directly to thousandths of an inch, but ten-

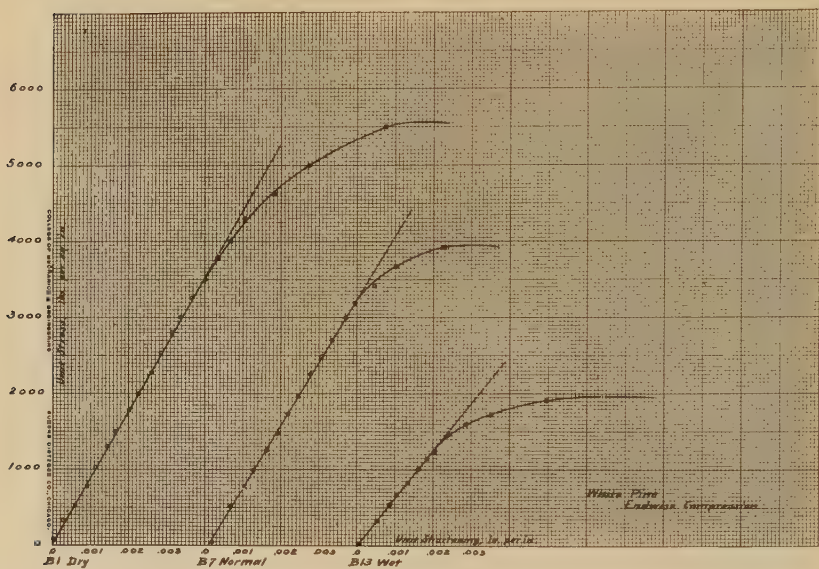

6000
5000
4000
3000
2000
1000
0 .001 .002 .003
0 .001 .002 .003
0 .001 .002 .003
B1 Dry
B7 Normal
B13 Wet
White Pine
Endwise Compression

FIG. 5.

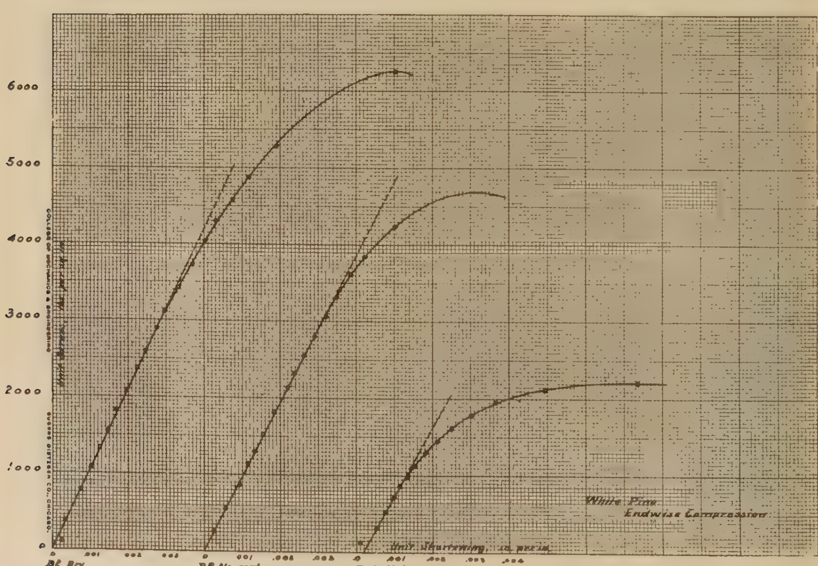

6000
5000
4000
3000
2000
1000
0
B2 Dry
B8 Normal
B14 Wet
White Pine
Endwise Compression

FIG. 6.

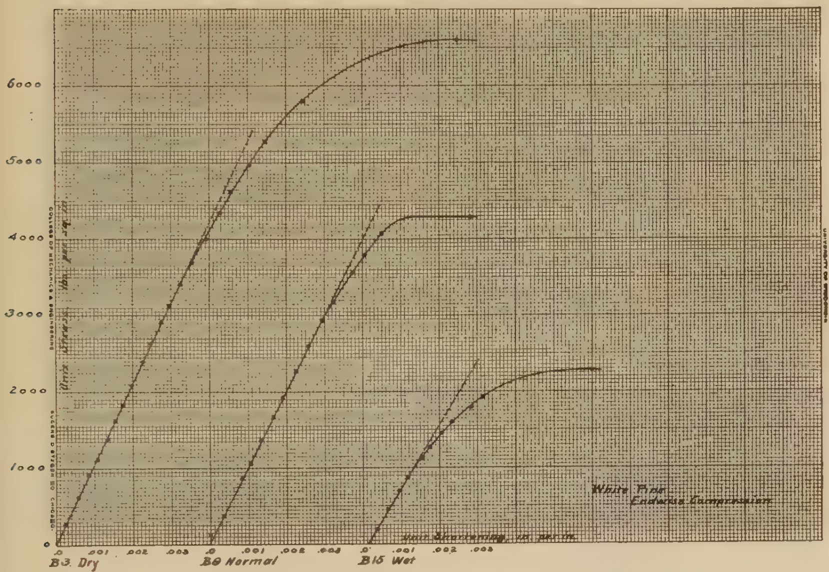

6000
5000
4000
3000
2000
1000
0
Unit Stress, lbs. per sq. in.
.0
.001
.002
.003
B3. Dry
B8 Normal
B15 Wet
Unit Shortening, in. per in.
White Pine
Endwise Compression

FIG. 7.

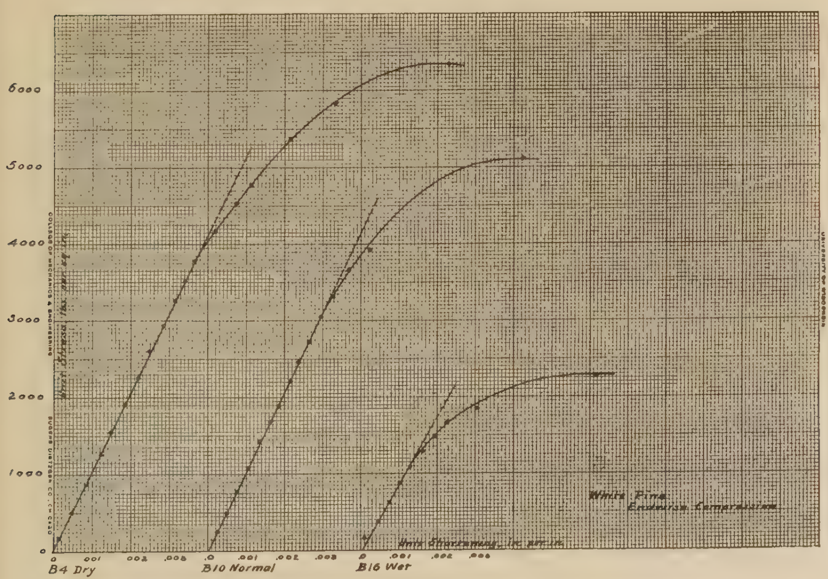

6000
5000
4000
3000
2000
1000
0
Unit Stress, lbs. per sq. in.
.001
.002
.003
B4 Dry
B10 Normal
B16 Wet
Unit Shortening, in. per in.
White Pine
Endwise Compression

FIG. 8.

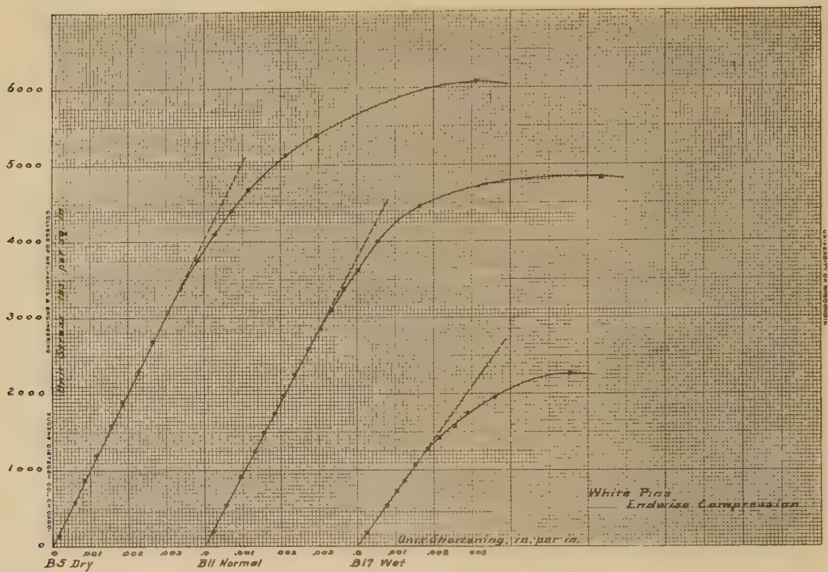

6000
5000
4000
3000
2000
1000
0
Unit Stress, lbs. per sq. in.
0 .001 .002 .003
.0 .001 .002 .003
.0 .001 .002 .003
B5 Dry
B11 Normal
B17 Wet
Unit Shortening, in. per in.
White Pine
Endwise Compression

FIG. 9.

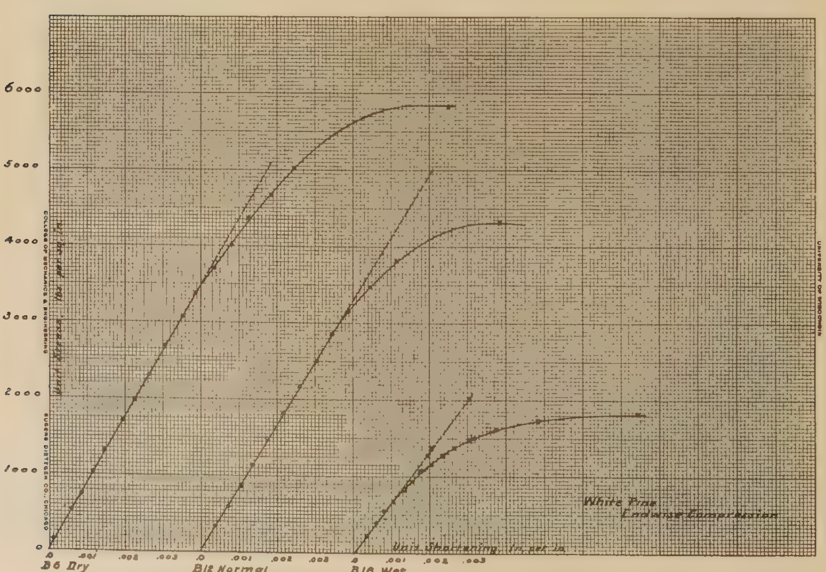

6000
5000
4000
3000
2000
1000
0
Unit Stress, lbs. per sq. in.
.0 .001 .002 .003
.0 .001 .002 .003
.0 .001 .002 .003
B6 Dry
B12 Normal
B18 Wet
Unit Shortening, in. per in.
White Pine
Endwise Compression

FIG. 10.

thousandths may be estimated with fair degree of accuracy. The method of measuring between compression blocks proves sufficiently accurate if a small initial load be applied before taking the first reading.

In the same manner, during the laboratory periods of the following two weeks, the remainder of the tests (Fig. 4), consisting of across grain compression (Figs. 12, 13 and 14), endwise tension, across grain tension, and along the grain shear, were completed; each student following a strip of the plank throughout its length through all these tests.

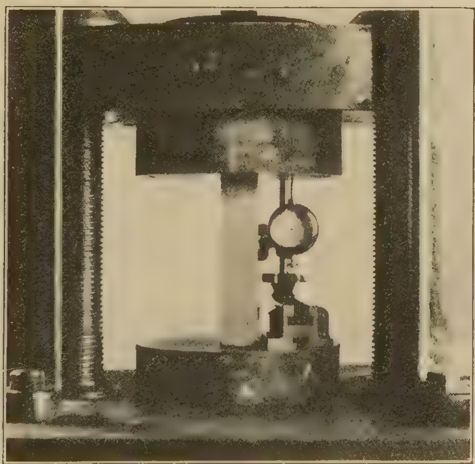


FIG. 11.

All the results were now tabulated and reported to the students on mimeographed sheets in the form shown in the table. These results were then plotted by the students with respect to position of the test specmens in the plank, to exhibit more clearly, the variations due to difference in the structure of the wood formed at different periods of the tree's growth (Fig. 15). On the whole these results are consistent, though but a single specimen represents each actual condition, and illustrate quite forcibly some of the variables in the strength of timber. There is another variable, however, which must be recognized before results like these can be used intelligently in designing, and that is the "time

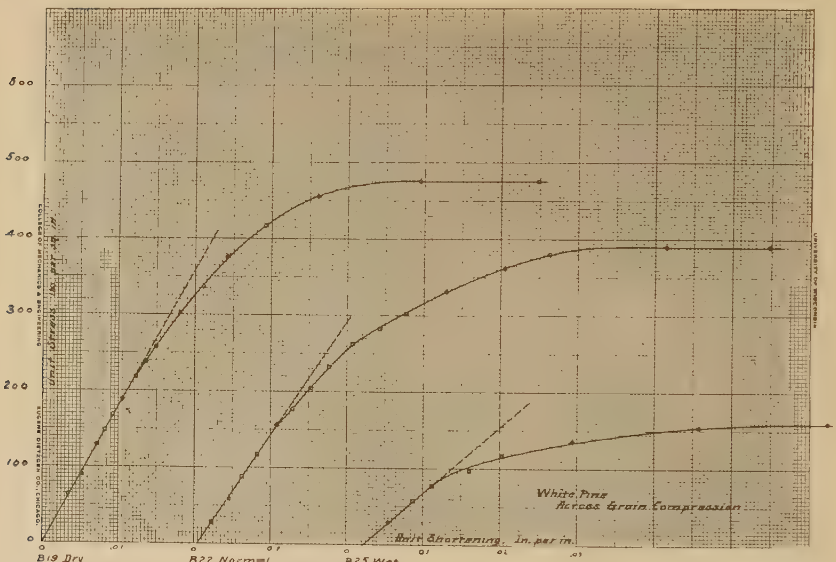

White Pine
Across Grain Compression
Unit Shortening, In. per in.
B19 Dry
B22 Normal
B25 Wet

FIG. 12.

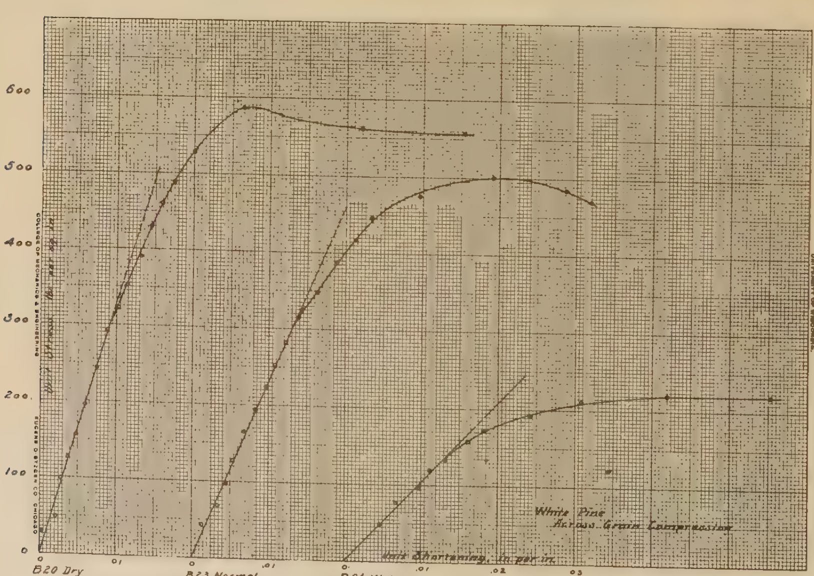

White Pine
Across Grain Compression
Unit Shortening, In. per in.
B20 Dry
B23 Normal
B26 Wet

FIG. 13.

effect." The strength of timber for permanent loads is only about 50 to 60 per cent. of these values; or, in other words, the ultimate strength of timber for a permanent load, is the same as the elastic limit for a short-time load. This may be illustrated to some extent, by a test like that of the three oak specimens shown in Fig. 4 with diagrams in Fig. 16. This, of course, cannot be carried out before the class on account of the long time required, but, if explained in object and plan, and kept

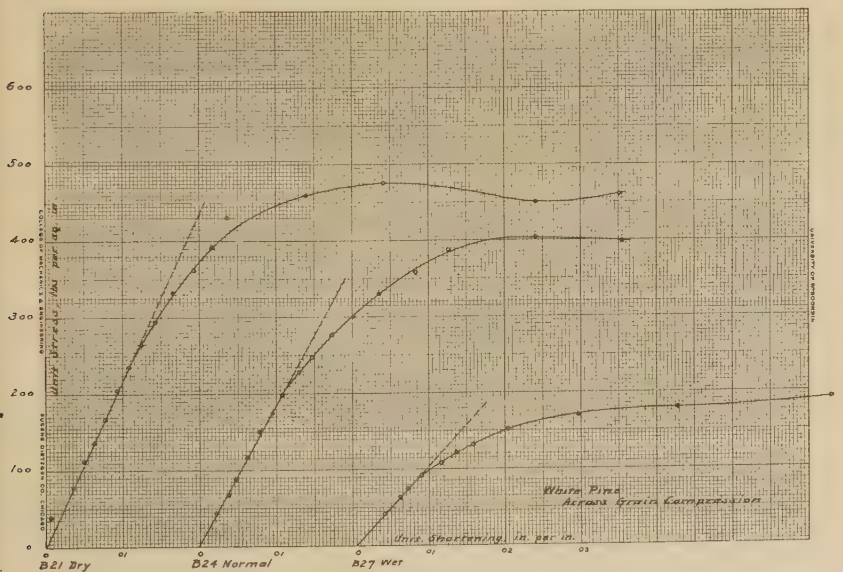


FIG. 14.

going during the week, will arouse much interest and discussion. The underlying motive in all this testing in connection with the class-room work should be to arouse the student, to make him see facts and relations clearly, to make him think. To this end also some simple problems in designing may be introduced from time to time, illustrating the practical use to be made of these test results. For instance, following the timber tests, the design of a low railroad trestle proves both interesting and instructive, requiring as it does a discussion of factors of safety

RESULTS OF TESTS OF WHITE PINE—SERIES B—PROPERTIES OF MATERIALS, 1904.

Endwise Compression.

								Average.	Relative Strength.
Elastic Limit	Dry	B1 3,300	B2 3,000	B3 3,300	B4 3,800	B5 3,200	B6 3,400	3,330	3.47
	Norm	B7 3,200	B8 2,900	B9 2,800	B10 3,000	B11 2,700	B12 2,900	2,917	3.04
	Wet	B13 1,200	B14 850	B15 850	B16 1,100	B17 1,150	B18 600	958	1
Ultimate Strength	Dry	B1 5,500	B2 6,250	B3 6,600	B4 6,340	B5 6,080	B6 5,830	6,100	2.85
	Norm	B7 3,930	B8 4,690	B9 4,290	B10 5,110	B11 4,820	B12 4,310	4,525	2.06
	Wet	B13 1,980	B14 2,210	B15 2,280	B16 2,280	B17 2,260	B18 1,820	2,138	1
Modulus of Elasticity	Dry	B1 885,000	B2 1,050,000	B3 1,055,000	B4 1,025,000	B5 1,010,000	B6 870,000	982,500	1.27
	Norm	B7 830,000	B8 965,000	B9 1,000,000	B10 1,040,000	B11 950,000	B12 820,000	934,200	1.21
	Wet	B13 626,000	B14 895,000	B15 840,000	B16 890,000	B17 700,000	B18 670,000	770,200	1

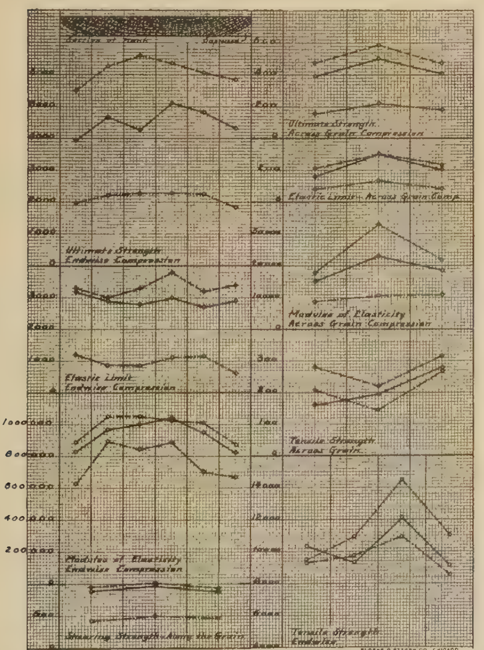
Across Grain Compression.

Elastic Limit	Dry	B19	210	B20	300	B21	235	248	2.55
	Norm	B22	160	B23	300	B24	200	220	2.27
	Wet	B25	80	B26	130	B27	80	97	1
Ultimate Strength	Dry	B19	475	B20	586	B21	475	512	2.75
	Norm	B22	390	B23	500	B24	403	431	2.32
	Wet	B25	159	B26	220	B27	179	186	1
Modulus of Elasticity	Dry	B19	17,960	B20	33,000	B21	21,800	24,250	2.42
	Norm	B22	15,000	B23	23,000	B24	18,300	18,770	1.88
	Wet	B25	8,650	B26	10,400	B27	10,960	10,000	1
Along Grain Shearing Strength	Dry	B28	948	B29	1,016	B30	941	968	2.06
	Norm	B31	886	B32	983	B33	863	911	1.99
	Wet	B34	416	B35	497	B36	460	458	1
Across Grain Tensile Strength	Dry	B37	280	B38	220	B39	316	272	1.31
	Norm	B40	159	B41	194	B42	277	210	1.01
	Wet	B43	208	B44	146	B45	266	207	1

						Average.	Relative Strength.
Endwise Tensile Strength	Dry	B46 9,440	B47 10,900	B48 14,500	B49 11,000	11,460	1.19
	Norm	B50 10,500	B51 8,950	B52 11,530	B53 8,210		
		B58 10,250	B59 9,600	B60 12,540	B61 10,080	10,207	1.06
	Wet	B54 9,320	B55 9,750	B56 10,950	B57 8,550	9,642	1
End. Ult. Com. Str.	Norm	4,250 4,850	5,100 5,040	5,340 4,890	4,920 4,940	4,916	2.17
	Wet	1,870 2,120	2,380 2,400	2,500 2,465	2,330 2,050	2,264	1

and allowances to be made for knots, seasoning checks, and decay.

Now taking up the different materials as cast iron, wrought iron, steel, in turn, it will be found the text-book can be used much more effectively. Every student now has some experience to be appealed to, and he is gradually beginning to think and express himself in the technical terms of strength and elasticity. Tests are now made only to illustrate some new method of testing or some peculiar property. Thus, a complete tensile test is made on a finished specimen of steel using an electric contact micrometer (Fig. 17). The broken ends of the steel or wrought iron specimens tested early in the course (Fig. 1), are retested to show the increase in strength due



Tests of White Pine — Series B — Strength in lbs. per sq. in. shown according to position of test-piece in plank, and under three conditions of moisture, viz.—
Dry (– – – –) Specimens dried over a boiler one week.
Normal (———) " as cut from the well seasoned plank.
Wet (—.—.—) " kept under water one week.

FIG. 15.

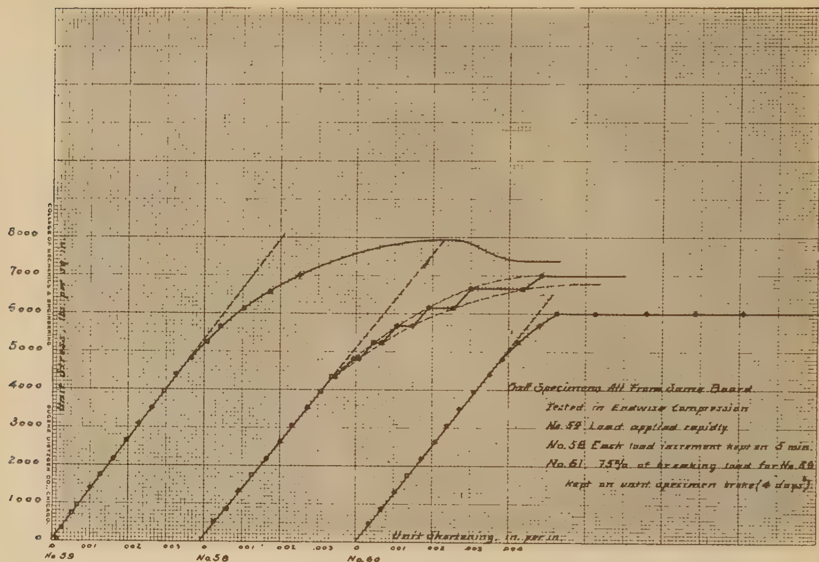

8000
7000
6000
5000
4000
3000
2000
1000
0
No 59
No 58
No. 60
Unit Shortening, in. per in.
Tested in Endwise Compression
No. 59 Load applied rapidly
No. 58 Each load increment kept on 5 min.
kept on until specimen broke (4 days).

FIG. 16.

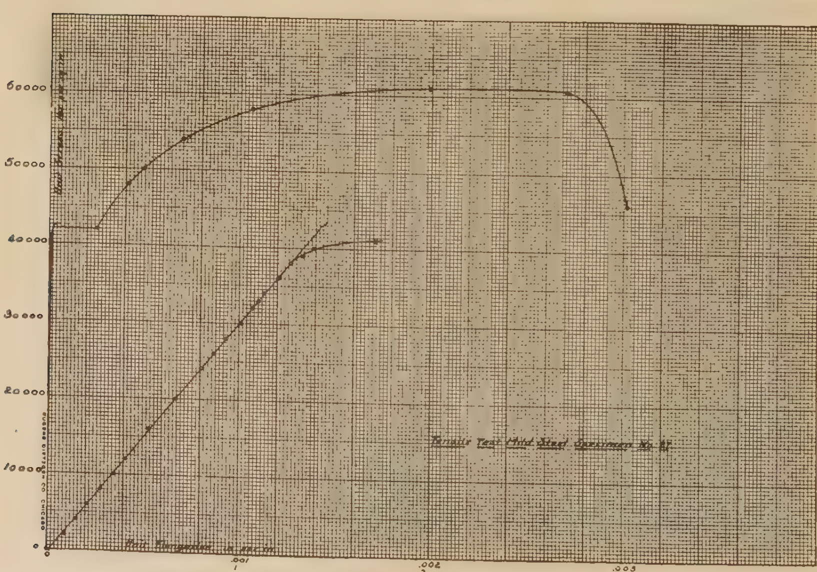

60000
50000
40000
30000
20000
10000
0
.001
.002
.003

FIG. 17.

to rest after cold-working. A torsion test on steel is made with the Thurston Autographic machine (Fig. 18a), another test on a specimen from the same bar to show the exaltation of the

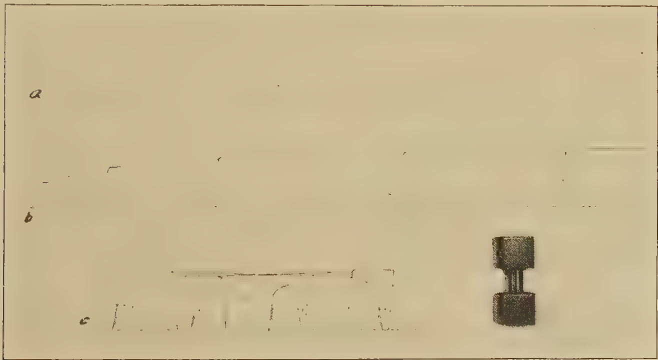


FIG. 18.

elastic limit (Fig. 18b), and a third (Fig. 18c), to show that the elastic field is fairly constant, and that raising the elastic limit in one direction reduces it in the other.

DISCUSSION.*

Mr. Hibbard.

Mr. H. Wade Hibbard.—There is one criticism that it seems to me might be made, which criticism is directed at the methods which have been necessitated, perhaps, by the increase in the numbers of students taking laboratory courses of this sort.

I know we shall all remember the Presidential Address this evening, and I hope that we shall give particular remembrance to the thoughts that Dr. Dudley brought out with regard to real education. It seems to me that in the multiplicity of experiments, in the desire on the part of the experimental laboratories to get a large number of experiments, somewhat varied, in the blank forms and careful directions, that the principle of education—real education—may be somewhat obscured. This, according to our President, is not the pumping into the student's mind of a large, amount of information, but the leading out from that student's mind, cultivating in that student's mind, the ability to reason for himself, to be ingenious and to plan for himself, and scheme out his methods for making experiments himself. That, of course, means that not so many experiments can be performed by students, but what they do perform they get in a fashion that gives them education in experimental methods, and in the ways of thinking as testing engineers.

Mr. Goss.

Mr. W. F. M. Goss.—The modern engineering laboratory contains apparatus of many different kinds. It has its steam engines, internal combustion engine, hydraulic apparatus and its machinery for testing materials. As I have followed the work of students along these different lines in a fairly busy laboratory, I have often been impressed with the fac that among them all none so well satisfy the requirements for the development of young men, as the material testing. Work along this line lends itself most readily to the instruction of students. In the department of

*Joint discussion of the two preceding papers, namely, "A Laboratory Course in Testing Materials of Construction," by W. K. Hatt, and "An Elementary Course in Properties of Materials," by G. L. Christensen.

testing materials, we are not liable to fall into those errors to which Professor Hibbard has referred. I am sure it is true that in all well-regulated laboratories the students in this department gather inspiration, their intellectual processes are quickened, they see purpose in the methods employed, and the working out of natural consequences in the results obtained. The whole tendency of the work is to arouse interest or enthusiasm. **Mr. Goss.**

I wish most heartily to commend the thorough manner in which the courses described have been systematized.

Mr. William Metcalf.—The thought that entered my mind just now in connection with the education of the engineer is the one prominently brought forth in the President's address, and that is, the importance of teaching a student to think. I think that is all that education is worth. I want to say a word here now that may seem proud, but I want to say a word for my alma mater. The one particular characteristic of that school throughout the whole course was, in my day, and I believe practically is now, that the student was taught only one thing at a time. He didn't have two hours a week at this, two hours a week at that, and two hours a week at another subject, and was not fed on mental hash all the way through so that at the end he would know everything: but every day and every week just one plain simple thing until he got through with that subject. The result was said to be tiresome by critics of the school. It was nothing of the kind. There was a little study in the morning, a little scientific recreation in the afternoon—the afternoon always given to some practical work, some laboratory work, drawing, etc., sufficient to teach the student at least the fundamentals of the tools he had to work with. He was always at one subject until he got through, and when he got through with it he generally knew it pretty well. **Mr. Metcalf.**

Mr. Mansfield Merriman.—In listening to these very interesting discussions regarding the conduct of laboratory work, I have been impressed with the large amount of labor spent by instructors to systematize the work and prepare the necessary plans in order that the student may derive benefit from them. It may, indeed, be thought by some that in many instances the greater part of the mental work is done by the instructor and that there is not much left for the student. There are blanks for every stage of the work, and it is sometimes carried so far that there is a **Mr. Merriman.**

Mr. Merriman. blank at one machine on pink paper and at another machine on brown paper. On each piece of paper there are lines half-printed and the student regards it as an academic exercise to fill out the dotted portions. This is probably an extreme view to take of the matter. If the student should come into the laboratory with the old-fashioned, small engineer's field book with horizontal and vertical lines on opposite pages, and be required to take down notes from the experiments and bring in the next day his own report in the way he thinks it ought to be arranged, it might be more advantageous to him in developing his power of thought. In large classes, however, such a plan would be imprac icable, and it may be said in favor of carefully prepared blanks that they give training in system and order. The papers that have been read hence present excellent solutions of the problems forced upon us in handling large numbers of students, and it must be said that great credit is due to instructors in laboratory work for the systematic methods which they are developing.

Mr. Lanza. MR. GAETANO LANZA.—Only two of the matters mentioned in the interesting and valuable paper of Professor Hatt will be referred to here. First, every competent teacher must constantly put forth his best efforts to make the students think for themselves, and the more completely he can accomplish this object, the greater will be the success attendant upon his teaching; as the student who only memorizes and does not think, is not competent to undertake the solution of such new problems as are constantly liable to arise in the practice of his profession. Second, the object of a graduating thesis is, to my mind, to teach the student how to make investigation. I prefer that the student should, if feasible, select the subject himself, the professor, of course, advising him, and not allowing him to take up a subject in which it is not possible for him to do good work. Then the student should, with the advice of the professor, map out a plan for carrying on the investigation, which, again, the professor should pass upon, and when the plan is properly arranged the student should perform the work.

Mr. Stoughton. MR. BRADLEY STOUGHTON.—One thing which you, Mr. President, have so well said at this meeting already, interested me very greatly, and I desire to refer to it again. That is, the propriety of studying, not the details of any practice, but the principles upon which that practice rests. It seems to me that, in this way,

Mr. Stoughton.

we should find a solution of the various questions we have been discussing here this evening. A student mind is a limited vessel, and if one tries to fill it too full, and especially too full of details, it begins to spill and leak very fast, so that the amount of knowledge which escapes is altogether disproportionate to the amount which remains. In our over-crowded laboratories it is a great temptation to adopt printed laboratory blanks, routine methods of instruction and systems which enable us to put a number of students through the motions of many tests in a limited time. But is this the best method of concentrating their attention on the principles which we desire them to absorb? True, they become momentarily acquainted with many details, some of the least important of which are repeated several times, but it gives them neither the encouragement nor the time for independent thought which alone impresses them with the underlying principles of their occupation, but which almost every man finds at first both tedious and unattractive.

Mr. Kent.

MR. WILLIAM KENT.—We have heard a good deal lately of teaching principles and not details. In order to get a correct knowledge of principles close attention should be given to details. One of my students had a knowledge of the principles of the connecting rod, but about the details all he knew was that it is a bar with two holes in it. He didn't know anything about the strap, key, the shape or thickness. His powers of observation or his habit of attention to details had not been cultivated enough. What he needed was more knowledge of details, as a foundation for his knowledge of principles.

Our professor of electrical engineering recently complained that his Junior students had not been sufficiently grounded in the fundamentals of electricity, information which they ought to get in the Sophomore year. I told him to write out fifteen or twenty questions covering the points in electrical physics which every student ought to be able to pass one hundred per cent. on before he comes into the Junior class. He wrote out the questions covering all the information a man actually needed before entering the Junior work, and there is no reason why every one of these questions ought not have been answered one hundred per cent. They were the fundamentals and went into details all right. The professor of physics was glad to have the list of questions and asked

Mr. Kent. me to give him fifteen or twenty questions on heat, the answers to which should be known thoroughly by every Junior student in mechanical engineering. Physics should be taught with reference to its application in engineering work, and the same might be said of other fundamental studies, such as mathematics and even English.

Mr. Hatt. MR. W. K. HATT (by letter).—Every one agrees that every effort should be used to prevent an unthinking performance of work on the part of students, and, if necessary, even efficiency of administration and the inculcation of method should be sacrificed to this end. In the paper of the speaker certain practices are described which lead the student to a thinking consideration of his work. It is also true that by properly prepared instruction sheets describing manipulation, etc., the instructor's time can be given to the desired end, and by properly prepared blank forms the student is relieved of purely clerical work and his time can be devoted to the thing in hand. It is in favor of the use of proper forms, that it is part of the duty of the instructor to inculcate system and good habits with respect to recording data. All this general discussion which has followed the paper is of interest but scarcely touches the point. The problem of the paper is one of meeting practical conditions of administration of a course so that the largest use of the equipment may be obtained without allowing the work to degenerate to a mere mechanical performance.

A LARGE HYDRAULIC TESTING MACHINE FOR UNIFORM LOADS.

By Robert A. Cummings.

The following is a brief description of a testing machine and its method of application. It was especially designed and constructed by the author during 1903, for the purpose of investigating shearing stresses in beams of reinforced concrete. These beams were freely supported and of variable spans. A uniformly distributed load was applied by this testing machine, the maximum being 5,000 pounds per lineal foot.

Many mechanical problems presented themselves in connection with the design and construction of this novel apparatus, partly on account of the temporary nature of its employment, but mainly because of the necessity for precision in the recorded results.

Hydraulic power was selected as the most practical for obtaining the large load requisite for the tests. It was decided that the best method for the distribution of the applied load was by means of a series of beams arranged as shown in the accompanying illustrations.* Short lengths of I beams were placed along the specimen beam, the points of application of the load being 12 inches apart longitudinally. Above the shorter lengths of I beams were arranged longer beams, the supported end of each one resting upon the center of two of the shorter, and above these again were still larger beams similarly arranged. This method afforded an absolutely uniform distribution of load upon the specimen under test.

The various specimens tested were 10″ x 18″ in cross section, the spans varying from 8 feet to 20 feet. It was assumed that the maximum deflection producing failure of the specimen would not exceed 2 inches. A large-scale diagram of the distribution beams was made to show the distortion of the loading with 2-inch deflection at the center. The curve of assumed deflections of specimen was plotted as a parabola, and the outlines of the lower beams

*Acknowledgment is made to the *Engineering News* and *Engineering Record* for the cuts used in this paper.

laid off at right angles to a tangent to the parabola at the points of application of the loads. The maximum horizontal movement was found to be in the upper beam and amounted to one-half of the assumed deflection of the specimen. The movements of the lower tier and hydraulic jacks were inappreciable. This diagram was found quite useful in designing the details.

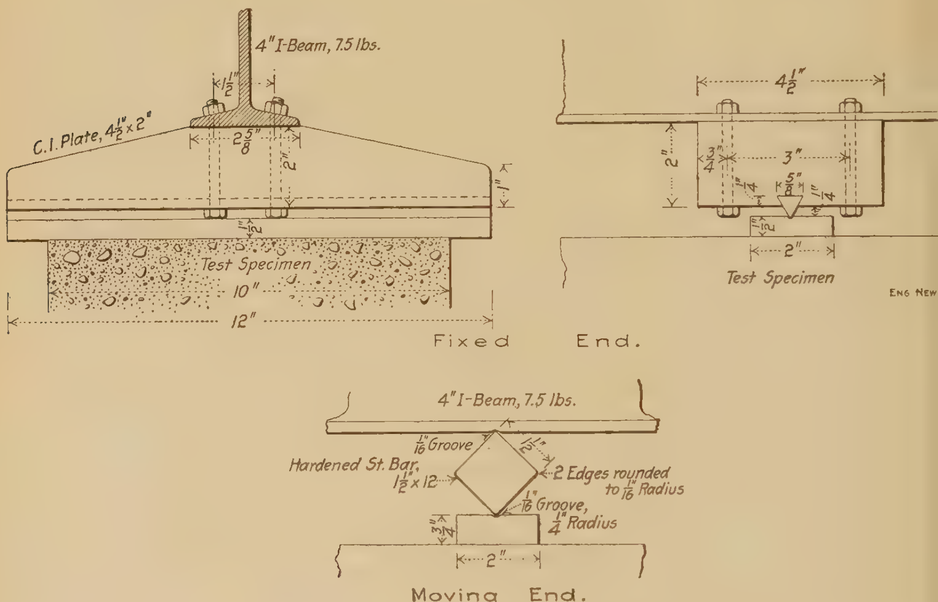


FIG. 2.—Fixed and Rocker Bearings Between Test and Last Equalizer.

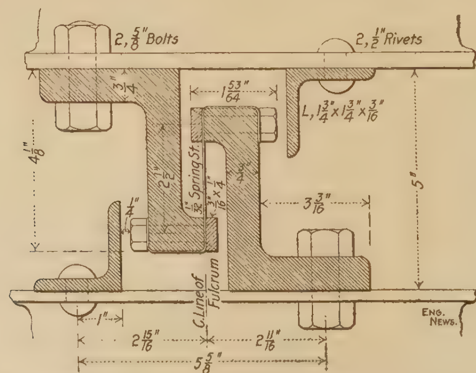


FIG. 3.—Membrane Suspension at Joints of Equalizer System.

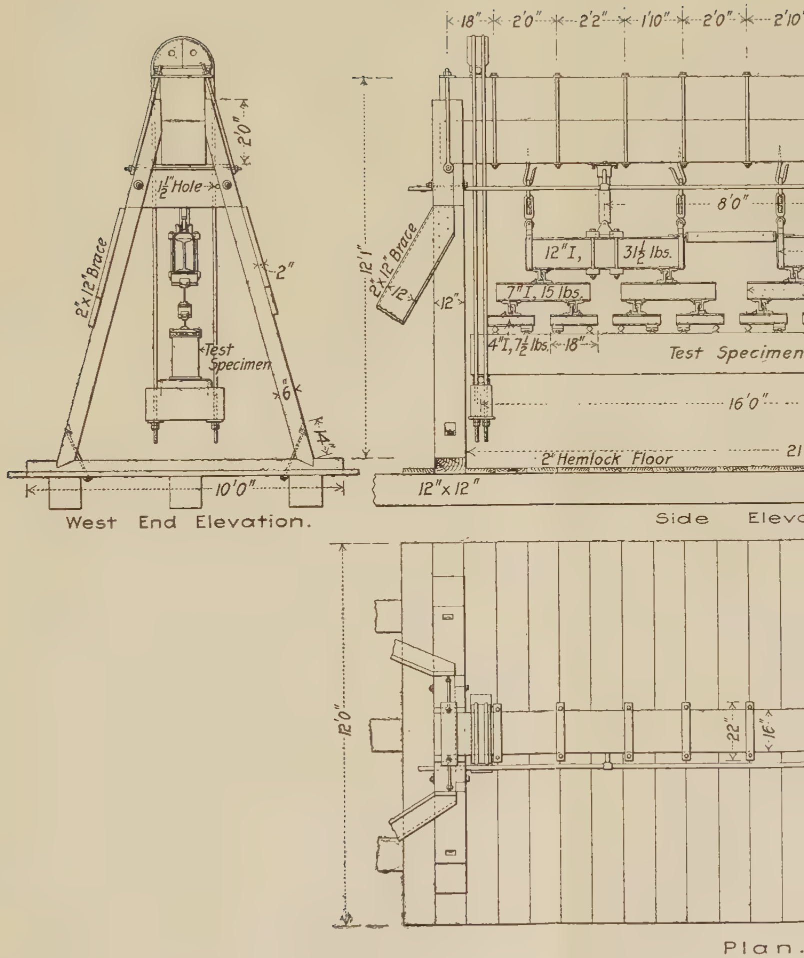
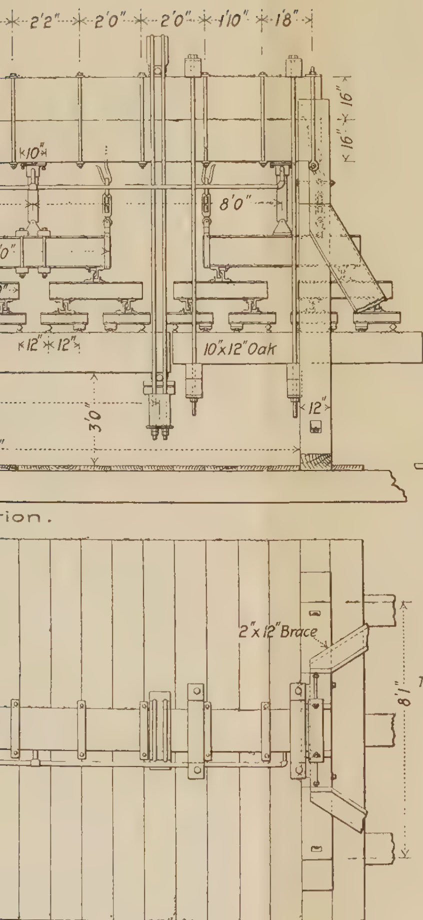
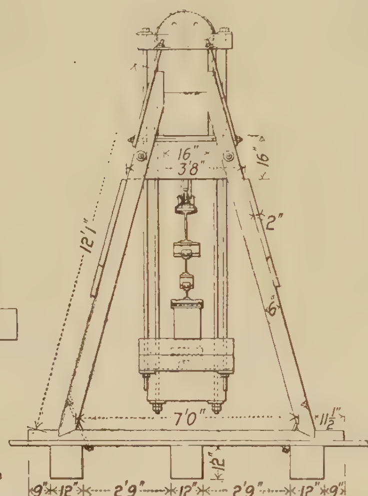


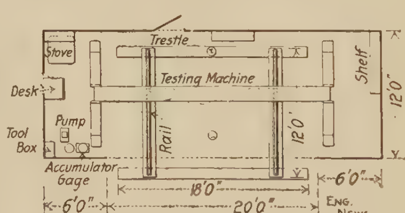
Fig. 1.—General Drawings of Cummin

Plate V.
Proc. Am. Soc. Test. Mats.
Volume V.
Cummings on Testing Machine for Uniform Loads.





East End Elevation



Arrangement of Frame Building for Testing Machine.

s' Uniform Load Beam-testing Machine.

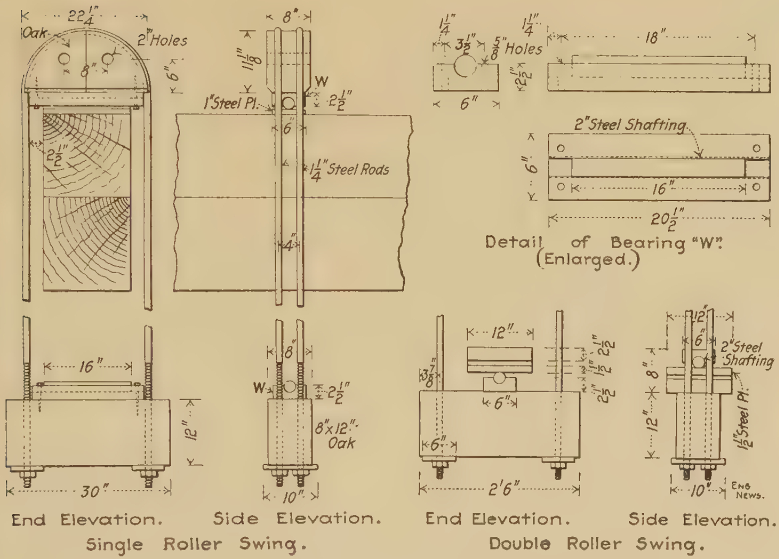


FIG. 4.—Roller-joint Stirrups for Supporting Ends of Test Beams.

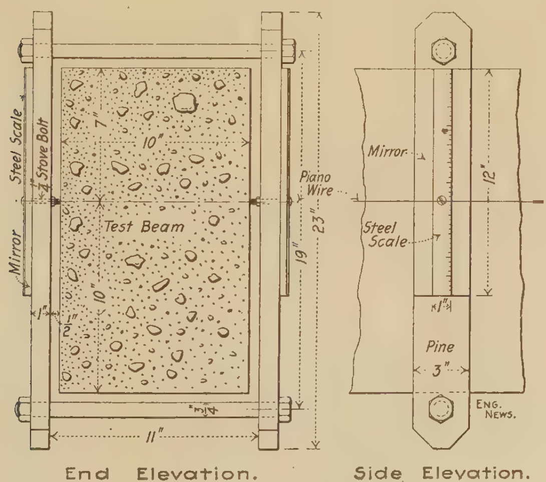


FIG. 5.—Mirror and Scale Yoke for Measuring Deflections of Test Beam.

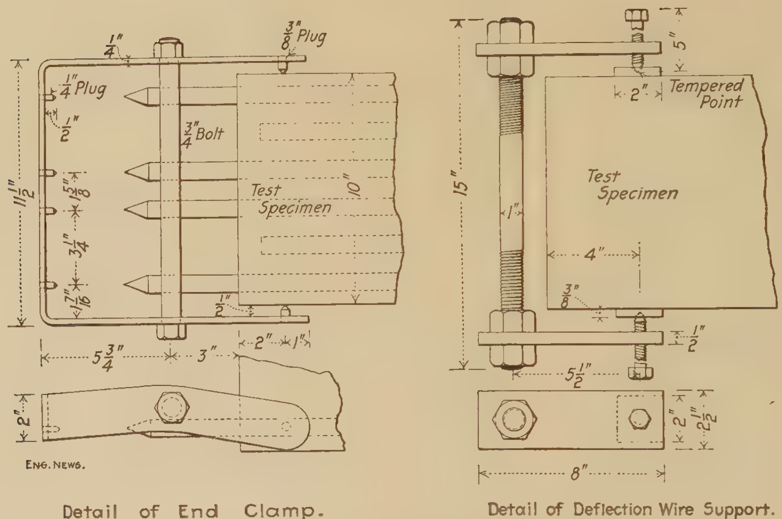


FIG. 6.—Details of Deflection Wire Support and End Clamp for Measuring Slips of Reinforcing Bar.

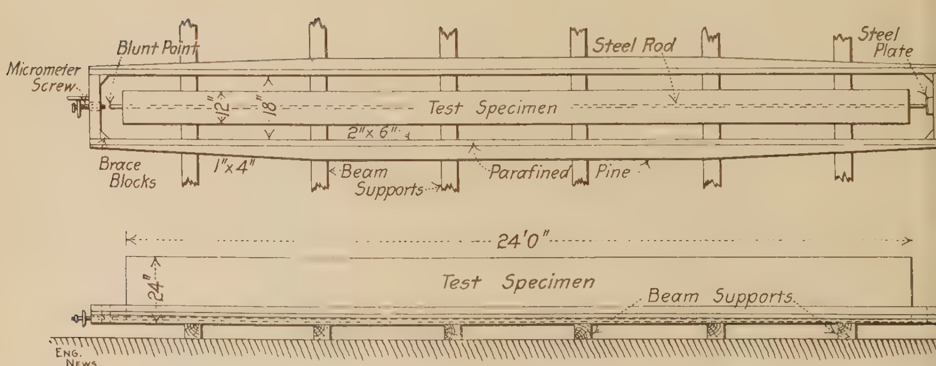


FIG. 7.—Micrometer Apparatus for Measuring the Initial Stress in Embedded Steel.

Numerous tests were carried out at the works of the author under his personal supervision by Mr. J. M. Gilman, who had previous experience in testing under Dean Turneaure of the Engineering Department of the University of Wisconsin. Every available convenience required for investigation was utilized. The testing machine was largely "home-made," with the exception of the excellent hydraulic apparatus which was generously loaned by Mr. F. H. Stillman of the firm of Watson-Stillman Co., manufacturers of hydraulic appliances, New York, to whom the author desires to record his obligations and thanks.

The operation of the testing machine required two observers, also a recorder and two handy-men, and the use of a steam derrick for moving the beams. When making a test, the beam was placed in position, with the observers stationed on either side to read the two sets of Professor Johnson's extensometers and the deflectometer. The observers announced the action of the beam to the recorder who entered the same on the prepared blanks. One handy-man operated the hydraulic force pump and another applied the weights as required on the spinning accumulator gauge. The application of load could thus be made at any rate of speed or repeated as often as needed. This feature of a hydraulic apparatus is especially useful for repetitive tests and for obtaining permanent set and the effect of speed in loading.

The spinning accumulator gauge was calibrated, and checked with a dial gauge for pressures up to 1,000 pounds per square inch. For pressure above 1,000 pounds and up to 5,000 pounds per square inch, the maximum capacity of the machine, the spinning accumulator gauge was used alone. A light oil instead of water was used for the hydraulic apparatus to avoid danger from freezing. On the completion of a test the handy-man replaced the tested specimen with an untested one. It required about one-half day to make a complete test of each specimen and to place another in position; usually two tests were completed in one day.

In calibrating the machine to get the actual applied load, two weighing machines having platform scales were placed on either side of the apparatus and supported the ends of a beam to take the weight at points of application of the load. This beam transmits the total load received to both scales which were read and recorded. Tests were made at several points of application, as

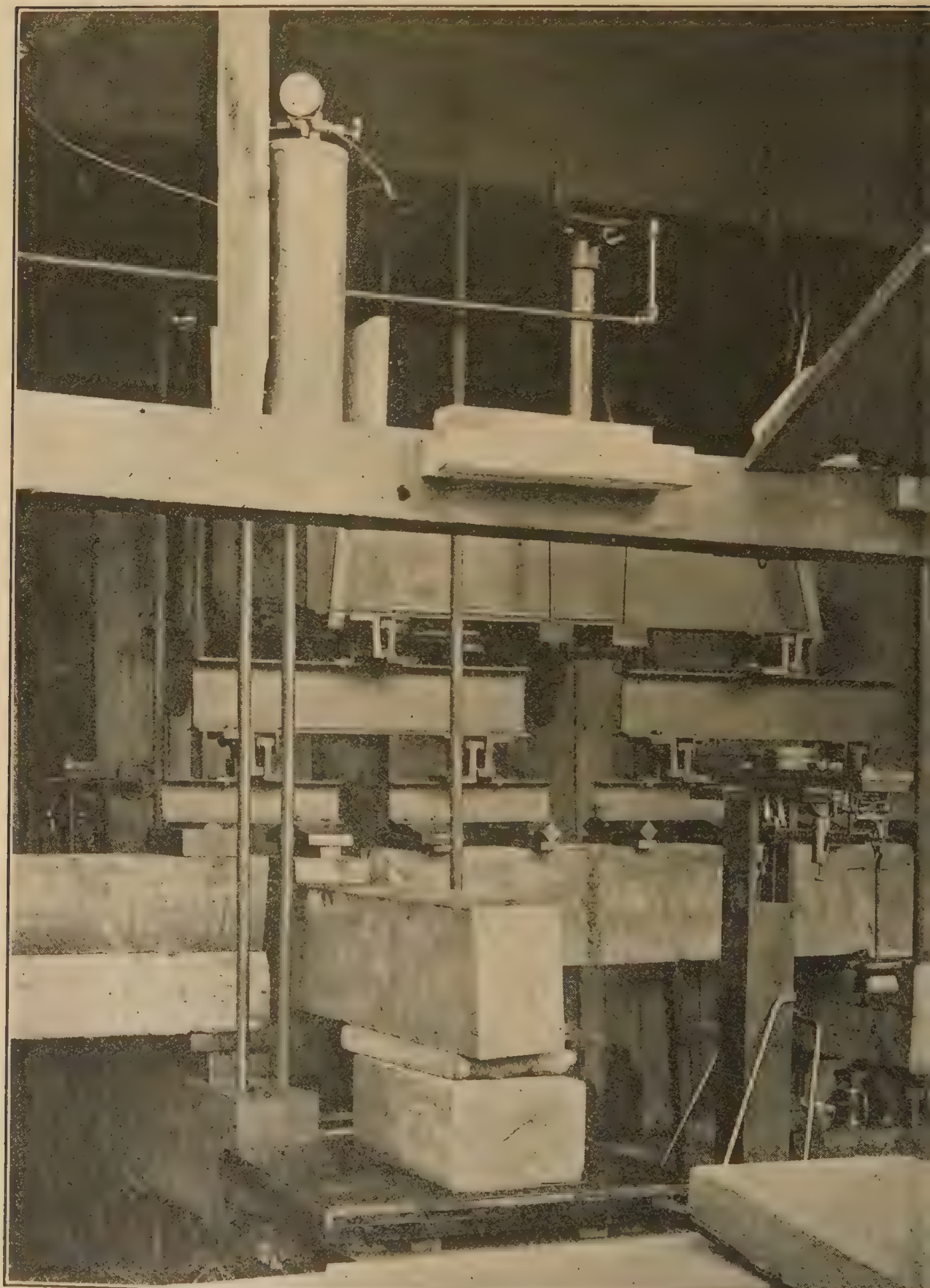


FIG. 8.—Weighing an Applied Load on Platform Scales for Calibrating the Testing Machi

shown in photograph illustrating the calibrating of the testing machine. Some of these were with 50-pound increments per half minute, and others with 100-pound increments at 1 and 2 minute intervals. These loadings were applied up to 5,000 pounds

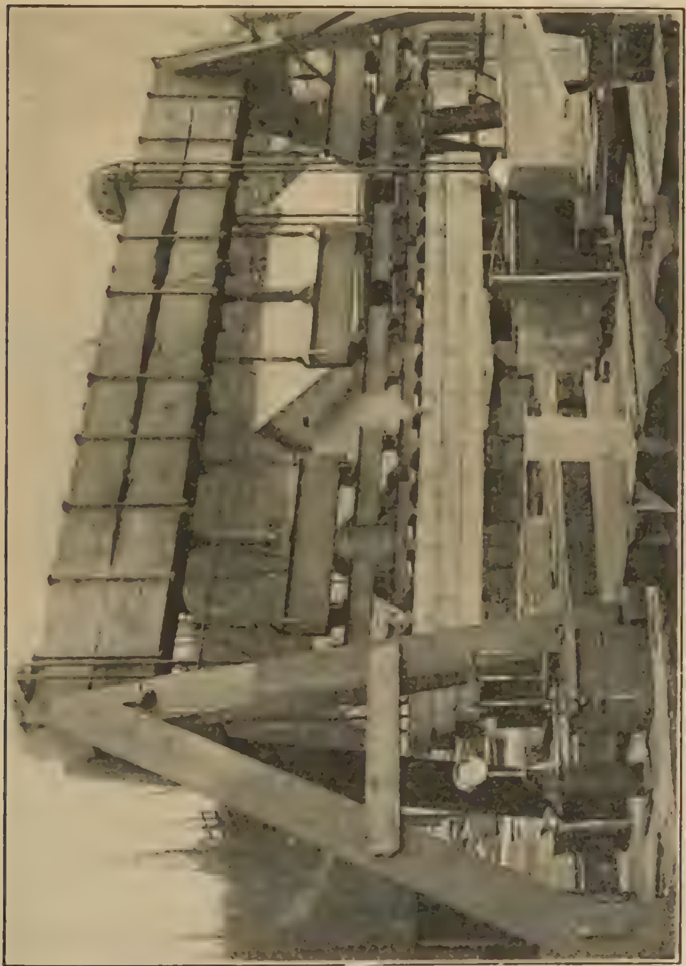


FIG. 9.—General View of Testing Machine Before Housing.

per square inch, which was the limit of the machine. The actual weight shown by the scales at each interval was recorded. Upon reaching the limit of the machine the load was released in a manner similar to its application.

It was desired to discover whether there was any material difference in applying the load at differing rates of speed. As a result it was determined that increments of 100 pounds per minute were most convenient, and secured the most uniform results. The records were plotted and the curves show that in every test, upon running up the load, the actual exceeded the computed weight, and in releasing this condition was reversed; the difference was probably due to internal friction of the hydraulic jacks.

When the load was retained at 5,000 pounds per square inch for 8 minutes there was a falling off of pressure.

In testing specimens the webs of the I beams finally buckled at maximum loads due to stretching of the spring steel fulcrums. To guard against a repetition of this we now use double I beams. The results of our tests are available in any really scientific research work.

The accompanying drawings show the testing machine in complete detail and make a lengthy description unnecessary.

SPECIFICATIONS FOR COTTON TAPES FOR ELECTRICAL PURPOSES.

By R. D. DeWolf.

In the making of a specification for a manufactured product, the more complex the manufacturing process, the more difficult it becomes to differentiate between the necessary and the superfluous restrictions to be embodied in the specification. Dr. Dudley has said, "A specification should contain the fewest restrictions consistent with obtaining the material desired," and "the service which the material is to perform should determine the limitations of a specification." These considerations are quite generally overlooked in the case of woven fabrics, the consumer binding the manufacturer down to very narrow limits in his selection of raw material, method of production, etc.

In making specifications for woven fabrics, especially in the cases of tapes, there is a general tendency to select a fabric which has been found to be satisfactory for the purpose in view, to analyze this, and to embody this analysis in permanent form as a specification. This method is open to criticism in that it allows the manufacturer no leeway in his selection of yarns, combinations of same, or method of manufacture. Specifications have recently been issued by the Westinghouse Electric and Manufacturing Company in which an endeavor has been made to overcome these objections, and the specifications so drawn as to allow the manufacturer the greatest possible variation consistent with the production of a fabric possessing the required characteristics.

Among the desirable qualities which should be embodied in a tape suitable for electrical purposes, we may note:

1. Sufficient strength to withstand any strain likely to be placed upon it.

2. A sufficiently close weave, varying with the thickness of the tape, to give a neat appearance and withstand abrasion.

3. Uniformity in width and thickness.

4. Sufficient absorptive power to become thoroughly impregnated with any suitable paint or varnish, giving a smooth, uniform finish when properly applied to the apparatus to be protected

The general method adopted in the specifications referred to may be briefly outlined as follows.

Taking the breaking strength of the warp of a tape as its determining factor, it is evident that this strength may be obtained by the use of a small number of large threads, a large number of small threads, or any combination of the two; hence, for a given breaking strength, a number of different tapes may be made up having a definite number of ends per inch in the warp for each size of yarn used; each of these tapes will, on test, show the required breaking strength and each will be "filled" to approximately the same extent ; that is, the ratio of the space filled up by the threads in the tape to the unfilled space between the threads, will be approximately the same. Any of these tapes will, then, be satisfactory for the purpose in view. Advantage has been taken of this principle in our specifications by specifying the breaking strength of the tape, leaving the selection of the size of yarn to be used, within specified limits, to the discretion of the manufacturer.

The breaking strength of a tape will be a certain proportion of the calculated strength, this factor varying, first, with the quality of yarn, which determines the strength of the individual threads, and, secondly, the method of weaving, which influences the number of threads actually broken when the tape first gives way on test. By the "calculated strength" is meant the strength of the tape found by adding together the values for the indiviffual warp threads.

For a given quality of yarn and method of weaving, it is, therefore, possible to determine the ratio between the breaking and calculated strength of a given tape; assuming a required breaking strength, we may then find the necessary calculated strength by the use of this factor, when the minimum number of ends per inch may be readily determined by the use of the table giving the strength of standard American cotton warp yarns, compiled by George Draper and Company. This method has been followed, and a table incorporated in the specification giving the minimum number of ends per inch required in the warp for any size yarn, the number specified being such that a tape filling the specification in

this respeet will possess the required breaking strength, provided a good quality of yarn has been used and that it has not been overcalandered.

Briefly summarizing, the minimum breaking strength of the tape is specified, and the table referred to above, giving the minimum number of warp ends for any size yarn, is included. This table, in effect, places a lower limit on the calculated strength of the tape. By designating these factors respectively as "breaking strength per inch width" and "ends per inch," the specification may be made to cover any width of tape of the same thickness. Limits are placed on the variation in width and thickness. By placing an upper limit on the thickness, the manufacturer is prevented from using excessively coarse, cheap yarns, as it would be impossible to reduce the tape to the required thickness except by such heavy calandering as to weaken the warp threads to such an extent that the breaking strength would be reduced to a point below the specified limit. Regarding the woof or filler, it is only necessary to specify the minimum number of threads or picks per inch, as the filler, within certain limits, affects the appearance of the tape only .

All yarns used in tapes for electrical purposes should be unbleached, as the bleaching process is likely to weaken the yarn and to leave bleaching chemicals present which may exert a corrosive action on metal parts. The tape, after weaving, should not be filled with any more starch or other compound than is absolutely necessary for the calandering process, and in case it is not necessary to calander the tape, it should receive no treatment whatever after leaving the loom.

In testing tapes for strength, it is necessary to use considerable care to prevent the tape from breaking at the jaws of the machine. Very satisfactory results have been obtained by the use of corrugated clamping surfaces, the tape being protected by thin sheets of paper folded around it. The sample should be carefully adjusted in the clamps so as to properly align it and distribute the strain evenly over its width, otherwise, the tape will tear from one edge rather than break across the entire section.

The specifications for tape outlined above may be more or less closely followed in the case of other woven fabrics. These specifications, which have been thoroughly taken up with the tape

manufacturers, have fulfilled our expectations with a fair degree of satisfaction, and it is believed that further application of these broader principles in making specifications for manufactured products which, at first sight, might seem simpler to designate by an exact analysis of a given sample, will bring the consumer and manufacturer into closer and more comprehensive relations.

THE RATTLER TEST FOR PAVING BRICK AS A SAFE METHOD OF DISCLOSING THE LIMIT OF PERMISSIBLE ABSORPTION.

By Edward Orton, Jr.,

I. The General Status of the Rattling and Absorption Tests.

In 1895 the National Brick Manufacturers' Association appointed a commission to study the testing of paving brick and to formulate standard methods for making such tests as they deemed useful. This commission, reinforced by various persons whom they drew into their deliberations at one time or another, did some good work, and their various reports have given to the public a set of methods for testing paving bricks which have been adopted more or less widely as standards by the engineers and municipalities of this country.

Their findings in brief were: 1st. That the rattler, or impact, or abrasion test, as it is variously called, is much the most valuable test of all for judging paving brick. 2d. That the absorption test is of little use, from the fact that danger from frost arises at different percentages of absorption in different clays, and also in the same clay, when manufactured by different processes, and therefore no limit of general application can be laid down. 3d. That the cross-breaking test is of little use, because it depends on factors of strength which are not seriously called into play in the use of paving brick. Its only use is in judging of uniformity of structure, and freedom from large interior flaws, and these facts are sufficiently developed by the rattler test, when made as prescribed. 4th. That the crushing test for paving brick is also useless, from the fact that no paving brick ever crushes from pressure in use in a street. It may possibly fail from shearing stresses, though this is rare. It may disintegrate by frost, or by impact, but never by the rolling friction of heavy loads. Hence, any estimate of the real quality of a paving brick based on the crushing

test is of no importance. 5th. In view of these conclusions, a complete and rigid test of specifications as to how the rattler test must be performed in order to make its results comparable, was promulgated, and while methods for the conduct of other tests were given also, it was specifically stated that the rattler test alone was recommended for deciding the merits of competing materials.

The use of the cross-breaking and crushing tests, though at one time common, has under the influence of these reports steadily declined, until it is now largely abandoned. The truth and accuracy of the conclusions reached by the commission on the subject of the absorption test have been accepted in many quarters, but not by any means in all—possibly scarcely a majority. Engineers are still found specifying absorption tests for their paving material in all parts of the country, and brick manufacturers, especially those whose material will not endure the rattler test well, are often found advocating absorption as being the only safe guide to endurance in judging paving brick.

It is a common fallacy that bricks of exceedingly low absorption and therefore of highly developed vitrification, are the best and most enduring in street use. The life of a paving brick depends on two factors: 1st, the wear of traffic; 2d, the deteriorating effects of weather. A brick may fail from either cause—or from both jointly. The wear of traffic depends on the quality or combination of qualities called toughness. Resistance to weather depends upon a number of qualities, but chiefly power to resist the crumbling action of frost. To test the toughness, the rattler test has been devised and is generally conceded to be much the best method of measuring that property. For determining the frost resisting power, the common method is the absorption test, rarely supplemented by actually freezing samples when filled to their capacity with water.

The misconception to which reference has been made is that both qualities, toughness and frost resistance, are necessarily united and measured by the one test, viz., absorption, and that the highly developed vitrification, which engineers have been demanding and manufacturers striving to furnish, is really likely to represent good wearing power. The fact is that a highly developed vitreous structure, while favorable to frost resistance, and to weather resistance in general, is distinctly unfavorable to tough-

ness, while the losses in street wear of bricks of average grade are so largely due to abrasion and impact, that gain of frost resistance at the expense of loss of toughness is fatal to their endurance.

Of course it is well known that no rock, either of artificial or natural origin, is wholly unaffected by weather. All go down in decay; but some go with great speed, while others are considered indestructible because they endure the little span of a human life without much visible loss of strength. In dealing with vitrified paving brick we are dealing with an artificial rock, generally of high weather-resisting power, and while it would in time be resolved by nature's forces back into its constituents, it will endure without apparent result the weathering of many, many years. Some brick were used for paving purposes in the first years of this industry (1885–1895) in this country which were far from being weather proof. They were unable to endure frost without visible and rapid crumbling. But, so well has the public become educated on this point, that an instance of the use of soft brick in a street is now really rare.

This brings us to the fact that the deterioration of paving brick is chiefly by abrasion and impact—or the actual *wear* of traffic. And, to provide material which is able to endure this kind of deterioration well, is the chief anxiety of the manufacturer of paving brick.

The ability to resist wear, or toughness, is a factor yet but little understood. It is not certainly known to be the result of any single element or mineral or any combination of such, in the brick's composition. Bricks of very diverse composition have developed excellent toughness. While on all sides it is admitted to be due to the combination of the constituent minerals of the clay by the pyro-chemical process of burning, it is not known from what particular degree of combination the most perfect results accrue. The loss of identity of every mineral grain of the original clay, and the blending of the whole into a glassy matrix is certainly not desirable. Glassy bodies are never tough. Neither is it known whether the tough structure is produced by stopping the process of vitrification at a time when a fluid matrix of silicate matter has barely cemented the larger constituent grains of the clay into an coherent mass, or whether the combination should go on until the bulk of the clay has been brought into a viscous

matrix which should then be so slowly cooled that out of it will crystallize a net work of new minerals, which knit the mass into a fibrous crystalline structure, similar to the natural rocks.

Whatever the facts may ultimately prove to be as regards the intimate causes of toughness in a vitrified clay body, the important thing for us all to understand is that for developing the toughness of a clay, it is just as easy to go too far in the burning as to go not far enough, and that overburned wares are certain to be brittle and weak, while underburned wares will be granular and weak. The former will chip, losing large flakes with each well placed blow, while the latter wears away by rubbing, or by blows, from the inability of the cementing matrix to hold the grains together.

Either structure will produce a poor street. The kind of wear will be different, and the wear caused by brittleness is apt to be less rapidly fatal than that caused by softness, but it is fatal to a smooth enduring street, just the same.

The position has been taken by the Commission of the National Brick Manufacturers' Association, that while low absorption and, therefore, good weather-resisting power does not carry with it the assumption of good wearing power, or toughness, the possession of good toughness as shown by the rattler test, is a sufficient guarantee of frost resistance: *i. e.*, a tough brick will not freeze, no matter what its absorption may be, while a brittle brick, no matter how frost-proof it may be, is undesirable as a paver. This view is not yet accepted by many engineers and some brick manufacturers, and the following investigation has been made in order to throw light upon this highly important point.

II. PLAN OF THE INVESTIGATION.

In order to get at the points involved, it was decided:

1st. To procure a large quantity of bricks from one firm, made from one material and burned by the same man, and representing all grades of vitrification from the softest salmon up to the hardest over-burned and misshapen cull.

2d. To classify these bricks accurately into a number of groups, on the basis of their absorption percentage.

3d. To test each group, represented by two or more rattler charges of equal absorption, for its toughness by the standard rattler test.

4th. To take one charge of each group, after completing the rattler test, and soak it full of water and then freeze it repeatedly to observe its ability to withstand frost.

5th. To finally compare the frozen and unfrozen charges of each group by a still further rattling of short duration, in order to see whether the frost had weakened them. It was expected in some instances that the bricks would visibly crumble by frost, while previous tests had shown that in other cases no apparent effect would be exerted, though some weakening might naturally be expected to occur.

6th. It was hoped that the results would show whether bricks of sufficient hardness to endure the rattling test with moderate losses would withstand freezing also, or whether power to withstand frost must be considered as a separate factor in a brick of otherwise proved value.

III. The Selection of the Materials for the Test.

The Portsmouth Pressed Brick Company, of Portsmouth, Ohio, through the courtesy and liberality of its President, Mr. H. S. Grimes, not only permitted the selection of the materials for the test from the supplies of bricks on their yard, but also agreed to defray the expense of the investigation up to a certain amount. Though this sum has been considerably exceeded, their contribution still constitutes the larger proportion of the total cost and it is due them to say that but for their ready help and encouragement, the investigation would not have been made at this time. It is a pleasure to make this acknowledgment of their broad-gauged liberality and public spirit.

The bricks were selected by the writer in person, who chipped each brick with a small hammer, observed its color, classified it in a scale of hardness consisting of nine grades as follows:

I. 40 Bricks. Soft Salmon.

The color of this sample was a light yellowish red. The brick was unshrunken, being about the size of the dry brick before burning. Its hardness was very low—could be freely cut with a knife, almost whittled. It was too soft to be used in ordinary building construction, except possibly as a filling material in a thick wall.

H. 40 Bricks. Red Building Brick.

The color was a light red—devoid of the yellow cast of the preceding group. The brick had shrunk materially, about one-half of the final shrinkage of the harder grades. The hardness was still poor—could be cut freely, but not whittled. It was hard enough for ordinary building purposes, but not for paving.

G. 40 Bricks. Soft No. 2 Pavers.

Color was at about its reddest stage—a good brick-red. The shrinkage had progressed to about 75 per cent. of the final amount. The hardness was now beyond cutting, but the brick could still be scratched. It was hard enough for sale as a No. 2 paver, though its use in street work would be a cause of anxiety to its maker.

F. 40 Bricks. Hard No. 2 Pavers.

The color was about the same as G—very little darker. The shrinkage was about the same as G. The fracture was glossy where kiln-checked, but stony on a new break. The hardness was such that only a scratch could be inflicted.

E. 40 Bricks. Soft No. 1 Pavers.

The color was dark red—without any brown as yet. The shrinkage was about up to its maximum. The hardness was also about maximum. Knife could not cut or scratch sample on a smooth surface. Body was dense and grains nearly all amalgamated into a tight matrix.

D. 40 Bricks. Good No. 1 Pavers.

The color was light chocolate brown, with a reddish cast. The fracture was smooth and conchoidal in places. Knife left a metallic streak without cutting. Shrinkage, maximum. A type of fine-appearing paving brick.

C. 40 Bricks. Best No. 1 Pavers.

Color chocolate or liver brown. Fracture smooth, inclining to conchoidal. Shrinkage maximum. Very hard, dense material.

B. 40 Bricks. Overburnt No. 1's.

Color, dark chocolate—no red left in it. Black border, $\frac{1}{4}$ to $\frac{1}{8}$ inches deep around exterior. Size, greater than C, due to minute vesicular structure, indicating beginning of breaking down of the clay into fusion. Fracture smooth, but not so glossy as before, owing to less density.

A. 40 Bricks. Overburnt Culls.

Color—greenish-black on exterior—chocolate brown to darker brown in interior—depth of exterior color from $\frac{1}{4}$ to $\frac{3}{4}$ inches. Many of the bricks were bent or twisted out of shape. Some were more markedly vesicular than others, but in general, they were not spongy to the unaided eye, except on the outer crust.

These 360 bricks, whose selection took nearly a day's careful labor and much sorting and comparison and the rejection of many intermediates, were shipped to Columbus in barrels.

IV. THE ABSORPTION TEST.

As the bricks had been taken from the open air piles, they were naturally in all stages of dampness. They were accordingly placed in a down-draft test kiln, and heated up cautiously in 12 hours to a temperature where the hand could not be kept in the kiln but a moment—probably 160 to 180° F. In the next 12 hours they were carefully increased up to about 250° F., so that an iron rod introduced into the kiln for a few moments would hiss slightly on wetting. The kiln was cooled down in 24 hours, with doors and wickets shut. This treatment was certainly sufficiently gentle to expel all water wi hout any possible danger of checking, or weakening the bricks, either hard or soft.

The thoroughly dried bricks were then weighed on a torsion balance sensitive to one gram They weighed from 4023 grams as a minimum, to 4767 grams maximum, the average being 4400 grams. A serial number was painted upon each brick with white lead as its weight was taken. The weighed and numbered bricks were then immersed in a large tank of water, and left there for 48 hours. At the end of this period they were removed, wiped dry with a towel, and weighed at once. The bricks were carried through in 3 or 4 batches in order that the time of absorption between the first and last weighed in any single batch might not be long enough to make a factor of variation.

When all the bricks had been reweighed, they were once more placed in the kiln and dried as before the absorption tes , the work of W. K. Hatt, and others, having shown that it is essential that the rattler test shall be conducted on dry materials only. The drying, weighing, soaking, reweighing, redrying and calculation

of results took the entire time of one man for about three weeks, including a number of night shifts spent in firing the kiln for drying purposes.

The results of the absorption test showed a wide range of figures, as was expected. The maximum was 16.11 per cent. on one of the salmon bricks, while the minimum was zero, or an amount not recognizable with certainty on the balance employed, whose range of accuracy was nominally 0.022 per cent., but at the speed at which it was necessary to make weighings was probably not accurate for amounts below 0.10 per cent. About 150 of the bricks showed no appreciable absorption, *i. e.*, less than 0.1 per cent.

The classification of the bricks into absorption groups was next undertaken. It was found, as was anticipated, that the absorption data did not wholly agree with the group classification by color and appearance, which had been used in the selection of the material at the factory. The latter had served its purpose in providing a lot of material of graduated absorptions, and the original group boundaries were now no longer needed, in the case of bricks showing appreciable absorption. In the case of the four hardest-burned groups, so little absorption was observed that the color grouping was retained for lack of anything better.

The following table shows the groups as arranged by the new grouping:

TABLE I.

New Group Designation.	Number of Brick Included.	Average Absorption. Per cent. of Dry Weights.	Maximum Absorption.	Minimum Absorption.	Range Between Maximum and Minimum.
O	9	15.02	16.11	14.27	1.84
N	27	13.44	14.26	12.74	1.52
M	18	11.72	12.72	10.62	2.10
L	18	9.26	10.41	8.37	2.04
K	18	7.06	8.28	6.32	1.96
J	27	5.60	6.30	5.14	1.16
I	27	4.65	5.12	4.22	0.90
H	27	3.70	4.15	3.21	0.94
G	18	2.45	3.19	1.46	1.73
F	18	0.89	1.44	0.48	0.96
E	18	0.27	0.48	0.11	0.37
D	27	0.086	....	....	....
C	27	0.046	....	....	....
B	36	0.080	....	....	....
A	36	0.014	....	....	....

This classification into groups was not wholly satisfactory. It would have been better if about three times as many bricks could have been treated, and then not less than four charges of nine each could have been chosen from each group; also by rejecting intermediates, a series of groups could have been obtained, whose adjacent extremes in no case could approach each other too closely.

In this work, for instance in groups G and F, the highest absorption in group F was 1.44, while the lowest of group G was 1.46. The ideal series would have been to have the maximum of each group separated from the minimum of the next group above by 0.5 per cent. absorption, and also to reduce the range of absorption in groups to about 0.5 per cent., while in this work it varied from 1 to 2 per cent. Thus the groups were not as homogenous as was desired, nor separated from each other by intervals as desired. In view of the small number of bricks in some of the groups however, it seemed better to incur these sources of criticism than to test smaller batches of bricks per group.

V. THE RATTLING TEST.

The dried and classified material was now run through the standard rattler test of the National Brick Manufacturers' Association. For those not familiar with this test the following outline is given:

1st. The barrel of the rattler is 28 inches in diameter by 20 inches in length.

2d. It is a 14-sided polygon in cross section, and supported on trunnions on either end, and with no shaft or obstruction in the barrel.

3d. It is built of cast iron heads, and either cast or wrought iron staves six inches wide.

4th. The spaces between staves for the escape of dust are not to exceed $\frac{3}{8}$ of an inch in width.

5th. The rate of rotation is 30 per minute, permission being given to fall as low as 28 or as high as 32 without vitiating the test.

6th. The number of revolutions per test are 1,800, requiring one hour at standard speed.

7th. The number of bricks composing the charge shall not exceed 12, nor fall below 9.

8th. For an official test two separate charges must be rattled, and the average loss of the two reported as the official result.

9th. The brick must be absolutely dry when tested.

10th. In addition to the bricks, there shall be included in each charge, 225 pounds of $1\frac{1}{2}$ inch cast iron cubes, which weigh when new about 0.88 pounds each, and also 75 pounds cast iron shot $2\frac{1}{2}$x$2\frac{1}{2}$x$4\frac{1}{2}$ inches and weighing when new about 7 pounds each.

11th. The shot of both sizes, wearing away rapidly in the test, must be replaced by new ones whenever they have lost 10 per cent. of their original weight. This requires a frequent inspection of the shot, and rejection of all below the limit of weight, and filling up to the standard with new material. Thus every charge contains cubes and shot in all stages of wear from new to the rejection limit.

The losses found in average paving bricks obtained by this process of testing vary from 12 to 25 per cent. Occasional figures below 10 per cent. have been reported, but they are very rare indeed and perhaps not fully authenticated. Losses up to 35 and 40 per cent. are common on materials submitted for test as paving bricks, but it is believed that such bricks are not used and are merely tested for information as to their possibilities.

There is no standard or limit set by the N. B. M. A., as to what constitutes an acceptable loss per cent. in this test. They rightly leave that question to the engineer who is to use the material, to determine. The figures in use in different localities naturally differ with the climate, the size of the town, the intensity of wear, the size of the loads likely to be hauled, etc. In Columbus, Ohio, the limit set is 18 per cent. loss on abrasion; no other test is employed. In Chicago, I am informed that the limit has been 17 per cent. at one time, and 15 per cent. at another. The latter figure is undoubtedly very severe, and can only be met by a small proportion of manufacturers. In my judgment 17 per cent. for heavy traffic streets and 20 per cent. for light residence streets constitute reasonable limits, which can be met by the makers of the great majority of the brands on the market, if they use proper care in sorting their product.

In this investigation the standard requirements were strictly observed, except that the shot were allowed to fall 15 per cent. below their initial weight before rejection instead of 10 per cent.;

their collective weight was carefully maintained at 300 pounds at all times. The charges were overhauled and rejections made every five rattlings. It is believed that this procedure accomplished in all respects the same results as where the strict letter of the law was observed.

In the following table the results of the rattler test are shown, together with the absorption data:

TABLE II.

New Group Designation.	Number of Charge.	Loss in Per cents of Initial Weight.	Average Loss.	Average Absorption. Per cents. of Dry Weight.	Remarks.
O	1	63.33	63.33	15.02	none broken.
N	1	48.36	48.94	13.44	none broken.
	2	48.35			none broken.
	3	50.11			none broken.
M	1	43.36	44.71	11.72	one broken.
	2	46.06			
L	1	31.52	35.12	9.26	two broken.
	2	38.73			three broken.
K	1	26.88	25.65	7.06	none broken.
	2	24.42			three broken.
J	1	23.74	23.09	5.60	none broken.
	2	22.56			one broken.
	3	22.99			one broken in 3 pieces.
I	1	18.02	18.42	4.65	none broken.
	2	19.55			one broken.
	3	17.71			none broken.
H	1	18.74	19.27	3.70	one broken.
	2	18.81			two broken, one in four pieces
	3	20.22			none broken.
G	1	17.45	17.71	2.45	none broken.
	2	17.97			none broken.
F	1	17.88	16.73	0.89	one broken.
	2	15.58			none broken.
E	1	17.22	17.88	0.27	one broken in several pieces.
	2	18.54			one broken.

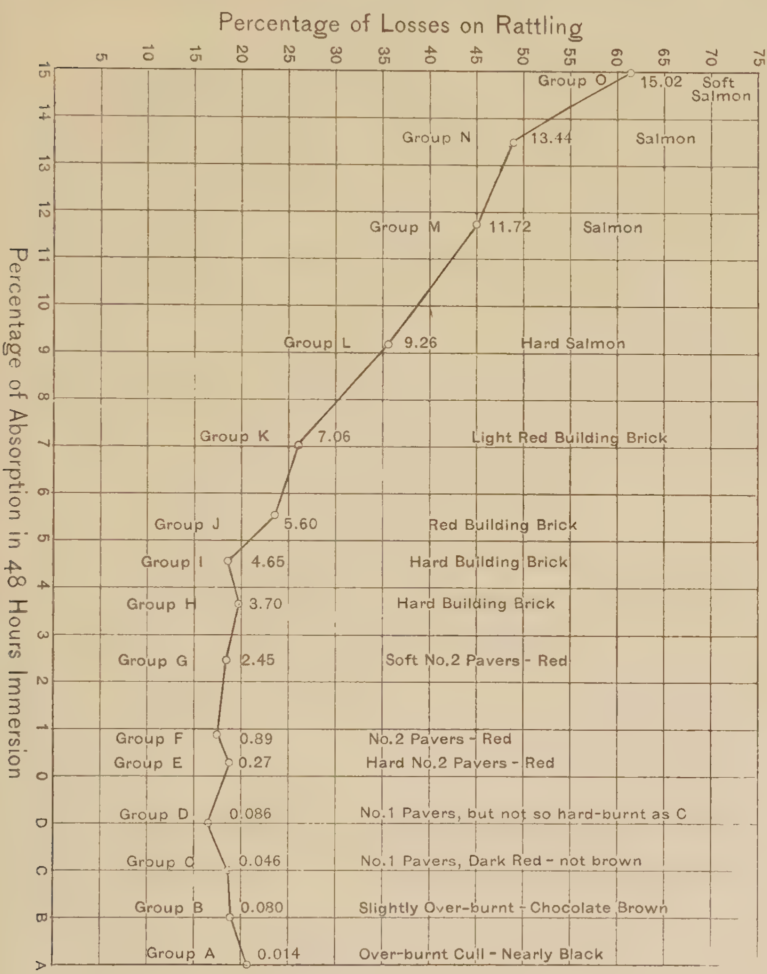
TABLE II.—Continued.

New Group Designation.	Number of Charge.	Loss in Per cents of Initial Weight.	Average Loss.	Average Absorption. Per cents of Dry Weight.	Remarks.
D	1	15.46	15.75	0.086	none broken.
	2	15.41			none broken.
	3	16.39			none broken.
C	1	16.42	17.60	0.046	one broken.
	2	16.38			one broken in halves.
	3	18.00			none broken.
B	1	18.70	18.07	0.080	two broken badly.
	2	17.58			four broken badly.
	3	17.87			one broken badly.
	4	18.15			one broken badly.
A	1	19.59	19.51	0.014	four broken badly, one in three pieces.
	2	21.46			two broken badly, one in small pieces.
	3	19.09			one broken.
	4	17.91			none broken.

The data shown above demonstrates a number of interesting things. Chief among these is the fact that the losses in rattling reach their minimum at what were selected as the softer No. 1 bricks, and rises regularly, though not rapidly, with every increase in hardness. Another significant point is that from Group I, whose absorption averages 4.65 per cent. and whose maximum was over 5 per cent , down to charge A, which was notably over-burned and chemically "reduced," the losses hover very closely around 17.88 per cent., which is the average for these nine groups. The fluctuation from this average is 0.54, 1.39, 0.17, 1.15, 0, 2.03, 0.28, 0.19, and 1.53 or 0.82 per cent. average. Moreover, the fluctuations are above and below without marked sequence, though there is a gradual descent to group D and a gradual ascent from it towards group A.

In order to bring out more clearly the relationships between these various quantities and properties, the following curve sheet has been prepared:

It will be observed that in the charges from I to F inclusive, which the manufacturer grades as seconds, the number of brick broken in the test was 7 out of 108 rattled, or 6.5 per cent. While



in the two groups C and D, which he grades as No. 1 hard and No. 1 soft, respectively, the broken bricks were 2 in 54, or 3.4 per cent. In the two hard groups A and B there were 15 bricks broken out of 72 or 20.8 per cent. This shows most powerfully

the weakening action of overfiring, which has reduced the element of strength without so rapidly affecting the element of hardness. The result is that the losses on abrasion are increasing slowly, while the proportion of breaks is increasing very rapidly indeed.

The rapid increase of losses by rattling with the increase in absorption above to 5 per cent. is most beautifully shown. It proves very clearly that for this clay, under this system of manufacture, and burned in this method, that substantially the full strength will be attained at a point far above that used by the manufacturer in grading his product. The question now hinges on whether this product comprised in groups I to E inclusive is frost-proof in the popular meaning of that term If they are, then the manufacturer is entitled to include them in his first-class output, and the engineer should gladly accept them, as they have a factor of safety from breakage over three times as great as the hard burned material, which is usually leniently inspected, and at the same time, a less rate of loss from ordinary wear.

V. THE FREEZING TEST.

In order to settle this highly interesting point, the charges from the rattler test, which had been carefully marked, were inspected and one charge from groups M, L, K, J, I, H, F and E was selected for freezing. The freezing test was limited to this number of charges, because of the time required to do the work, and because the question practically at issue did not require the extremely soft or the extremely hard bricks to be tested. The location of the limits of safe absorption between these extremes was the point to be settled, and the charges selected for test seemed to cover that range. In order to make the comparisons as fair as possible, bricks which had been broken in the rattler were ruled out, and the comparison made on rattled whole brick only.

TABLE III.

CHARGES SELECTED FOR FINAL COMPARISON.

Frozen.			Not Frozen		
Group.	Number Bricks.	Weight.	Group.	Number Bricks.	Weight.
M—2	9 bricks	47.5	M—1	9 bricks	49.5
L—1	6 bricks	40.9	L—2	6 bricks	40.1
K—2	6 bricks	43.0	K—1	6 bricks	43.5
J—1	8 bricks	58.0	J—2	8 bricks	59.6
I—1	9 bricks	71.0	I—3	9 bricks	70.4
H—3	9 bricks	70.6	H—1	9 bricks	70.6
G—1	9 bricks	71.8	G—2	9 bricks	71.5
F—1	8 bricks	63.8	F—2	8 bricks	64.8
E—1	8 bricks	64.6	E—2	8 bricks	64.7

The charges to be frozen were next soaked for 48 hours preparatory to freezing; they were then weighed, and their absorption percentages recalculated. The soaking this time having been done after the bricks were much worn and their surface opened up to the attack of water, naturally took a larger proportion than at the previous determination. The figures are as follows:

TABLE IV.

Group Designation.	Charge Number.	Original Absorption of Group.	Absorption After Rattling.
M..............	2	11.72	12.84
L	1	9.26	10.19
K..............	2	7.06	8.21
J	1	5.60	6.28
I	1	4.65	5.07
H..............	3	3.70	4.10
G	1	2.45	3.20
F	1	0.89	1.41
E	1	0.27	0.77

The charges were then placed in freezing boxes of iron, 12″x″22″x18″deep, the lids bolted down water tight and submerged in the brine tanks of the Indianola Ice Company. The writer desires to acknowledge his indebtedness to Mr. W. F. Polley, Manager, for favors extended in this connection.

The temperature varied from 13 to 17 degrees Fahrenheit. The bricks substantially filled the boxes, but were not allowed to touch the bottom or sides, and were separated from each other by pieces of lath. They were kept submerged for 22 hours. They were then taken out, opened, the box filled with hot water, and the bricks thawed for 1 hour, or until warm through and through. They were then shut up and refrozen, this treatment being repeated five times consecutively, each treatment consuming one day. The bricks were generally covered with frost when the box was opened, *or became covered after standing a few minutes in the open air*, showing that they were cold enough to freeze the moisture condensed from the atmosphere. A bottle of water placed in the box between the bricks was frozen solid when removed, though separated from contact with the sides of the box with 6 inches of air insulation.

In no case did the bricks visibly or decidedly fail in the freezing. The soft groups M and L gave off a little granular brick dust on handling, but did not chip or flake. The harder groups were absolutely unaffected, so far as could be seen. There is no question but that what water they contained was frozen each time.

The results of this part of the test were not wholly a surprise, as great difficulty had been experienced in former work, in damaging clay products of even higher absorption by freezing. Records have been published of tests on products holding 20 per cent. water withstanding repeated freezing without damage.

On the other hand, every engineer knows that soft burned bricks are unreliable and often go down by frost; many of them with smaller amounts of absorption than those included in this test. This brings in other factors which can only be explained in part at this time.

1st. Different clays respond to freezing with very different behavior. Some stand very little, and others very much.

2d. The process of manufacture makes a very great difference in the structure of the product and the resultant physical strength and resisting power to frost and abrasion. In general, soft mud bricks stand frost best, stiff mud next, and dry pressed least.

3d. The shape of the ware and the suddenness of the application are also very influential. Sudden heavy freezing applied on

all sides at once is most powerful for disruption, and slow freezing from one side only is least destructive.

Whatever may be the facts on this general question of an effective freezing test for clay wares, the fact remains that in this instance, while thorough freezing was accomplished five times consecutively, it produced no visible effect on the wares.

However, it is unsafe to conclude that no damage has been done because none is visible. Accordingly, the frozen charges were taken to the laboratory and once more dried out in the kiln, using 24 hours for this purpose, and cooling 24 hours longer. The dried charges were now ready for re-rattling.

The periods of rattling were very short, because it was desired to see whether the surface wore away faster in the frozen bricks than in the unfrozen ones. If the body were weaker superficially, but not affected to any depth by the frost action, then the first few moments of wear would show a difference between the losses of the frozen and unfrozen charges. If the body were unaffected by the freezing, then the two charges ought to show a very closely comparable loss, because each set of bricks had been reduced by the original rattling test to rounded masses, shorn of their corners and edges. The study of great numbers of rattler curves, where the losses have been measured at every ten minutes, and plotted, have shown that during the early portion of a rattling test the, accidental feature is very high, and large losses by the breaking off of big pieces are frequent. As the test progresses, the masses tend to take the form of spheres, and then the losses by spalling becomes less and less, and the steady *wearing* loss becomes nearly uniform for any given material.

From this it was expected that these rounded bricks would give closely agreeing losses in each duplicate charge, unless the frost factor were to introduce a new cause of variation.

The rattlings were made in three separate periods, two of three minutes each, and one of four minutes, or ten minutes in all. The greatest care was used to see that the work was strictly comparable throughout.

TABLE V.

Group Designation.	Charge No.	Treatment.	Rattler Losses. 3 Min.	Rattler Losses. 6 Min.	Rattler Losses. 10 Min	Absorption After Rattling.
M	2	frozen	2.29	4.58	7.79	12.84
	1	unfrozen	2.27	4.54	7.73	
L.......	1	frozen	1.22	2.93	4.39	10.19
	2	unfrozen	1.49	2.98	4.72	
K	2	frozen	1.16	2.20	3.47	8.21
	1	unfrozen	0.92	2.06	3.45	
J	1	frozen	0.68	1.02	2.06	6.28
	2	unfrozen	0.50	0.83	1.85	
I.......	1	frozen	0.42	1.12	1.68	5.07
	3	unfrozen	0.56	1.13	2.12	
H	3	frozen	0.14	0.70	1.27	4.10
	1	unfrozen	0.56	1.13	1.98	
G.......	1	frozen	0.27	0.69	1.25	3.20
	2	unfrozen	0.27	0.83	1.25	
F.......	1	frozen	0.47	0.94	1.41	1.41
	2	unfrozen	0.30	0.61	1.39	
E	1	frozen	0.61	0.92	2.01	0.77
	2	unfrozen	0.46	0.77	1.39	

It must be understood that the above rattling tests are only comparable with each other, group by group, and not group with group. As the charges consisted only of the whole bricks left from the previous rattling of each charge, and therefore varied from 6 to 9 bricks per charge, it will be impossible to accurately connect the performance of each charge with its rate of loss before freezing. It is only possible to compare it with another charge of the same absorption, same number of bricks and worn to about the same degree by an identical treatment, except as to freezing.

A scrutiny of the results shown in Table V develops the following points:

1st. After three minutes' rattling, which should be especially destructive to bricks whose surface had been weakened by repeated freezing, the nine charges stood as follows:

Cases where frozen losses exceeded unfrozen......4—K, J, F, E.
Cases where losses were about equal...............2—M, G.
Cases where unfrozen losses exceeded frozen......3—L, I, H.

The our frozen samples which lost more heavily than their unfrozen companion charges, varied from 8.21 per cent. absorption to 0.77 per cent. The three cases where frozen charges stood more than the unfrozen, had absorptions of 10.19, 5.07 and 4.10 respectively. The charges of equal loss had absorptions of 12.84 and 3.20. In no case did the loss of one charge exceed that of its compnaion charge by a large amount, or one beyond the usual limit of fluctuation of unfrozen charges.

Nothing can be shown from this data, except that the freezing has not affected the softer bricks more than it has the harder ones.

2d. After six minutes' rattling, during which the loose material, if any existed, should have been pretty well worn off from the exterior of the frozen brick, the records show:

Cases where frozen losses exceed unfrozen .....4—K, J, F, E.
Cases where losses are about equal.............3—M, L, I.
Cases where unfrozen losses are highest ....2—H, G.

It will be noted that there was a shifting around of positions during this test, G dropping down to the heavier losses, while L and I become equal.

3d. After ten minutes' rattling, beyond which it was thought not worth while to go, the charges stood as follows:

Cases where frozen losses exceeded unfrozen ...2—J, E.
Cases where losses are about equal ....4—M, K, G, F.
Cases where unfrozen losses exceed frozen .....3—L, I, H.

A still further shifting has here occurred, indicating the tendency of the charges to become more nearly uniform in rate of wear.

These facts seem to show that in this instance and under these conditions that the freezing treatment given was insufficient to produce any clearly marked effect. The charges which lost most were not grouped systematically towards either high or low absorption—in fact, their erratic distribution all over the range forces one to believe that the inherent irregularities of the material were more influential than the effect of frost, and that the variation observed resulted from this inherent irregularity and do not indicate anything else.

This frost treatment is unsatisfactory to the writer because its results do not correspond with the general observation that soft burned clay wares do deteriorate on freezing. It was expected

that charges M, L and probably K would show marked deterioration, but it was also confidently expected that charges I, H, G, etc., would not. The results were somewhat disappointing in that no clear cut distinction can be drawn between the hard and soft end of the series.

There remains two courses to pursue: 1st. To devise a much more sudden and heavy freezing test, by which bricks previously soaked full of water can be rapidly reduced to a point well below freezing. 2d. To expose the material to nature's alternations of freezing and thawing. In the case of this investigation the latter course is available, and the charges will half of them be exposed next winter, and in the spring be re-rattled in comparison with the protected charges, to see if any further clue can be gotten. This method, unfortunately, is too slow for a laboratory process and gives no relief in the matter of using the freezing test for determining practical questions when they arrive.

SUMMARY.

This investigation, in the opinion of the writer, shows the following points:

1st. That this clay, under the manufacturing treatment given by this company, reaches its maturity as regards toughness and ability to resist impact and abrasion, at an absorption of about 5 per cent.

2d. That at this stage, its color is still light red, and its fracture far from vitreous, and it would be condemned by most engineers and most paving brick manufacturers as "*too soft.*"

3d. That no important or consistent gains in strength or toughness are found on burning the material harder, through the dark red, and chocolate-colored stages, where the absorption falls below 1 per cent.; but neither is there any marked falling off. The gains in density and hardness offset the losses by increased brittleness, so that rattling losses remain about uniform during this period.

4th. Burning beyond the chocolate colored stage is invariably a source of deterioration. The hardness and density reach their maximum, while the clay is still dark red. Brittleness continues to increase, and with it a vesicular structure begins to appear, so

that the brick fails both by breaking, chipping and wearing. The percentage losses on rattling do not increase as rapidly from over-burning as from underfiring, but the percentage of broken bricks increases very much more rapidly, and they are a very serious cause of street failures.

5th. The weather resisting power of those bricks *which have reached their strength maturity, while still of relatively high absorption*, has not yet been conclusively proven. Five consecutive heavy freezings and thawings failed to weaken their structure. Whether a still larger number of repetitions would do so is not yet known. The test would be accepted with much more confidence if other still softer samples, which have not reached their strength maturity, had been damaged by these same freezing tests. Such was not the case, however, and this must mean, either that these freezing tests were inadequate, or that the material becomes frost-proof a long time before it reaches its best strength, and at a much greater absorption percentage than has been considered possible hitherto.

As a whole, in the opinion of the writer, the value of the rattler test as a means of judging the value of paving material has been clearly proven, and the contention that bricks which will endure the standard rattler test creditably will also endure the effect of frost creditably has been materially strengthened, but not yet conclusively proven.

In conclusion, the writer desires to give public thanks to Mr. Lester Ogden, who has carried out the large amount of work in this investigation with the greatest fidelity and attention to detail.

NORMAL CONSISTENCY TESTS OF NEAT CEMENT.

By Russell S. Greenman.

It is not because I expect to give you any information of value that I am about to open a discussion on this subject of "Normal Consistency Tests of Neat Cement," but rather because of a desire to obtain information for the department with which I am connected. The line of discussion which I shall undertake will be the relationship of normal consistency of neat cement to the time of setting.

Our laboratory being an unknown quantity to most of you, I hope you will pardon a brief statement of our interest in this subject because of the conditions as we find them. Perhaps such a statemen. will enable you to better understand our desires in regard to the information sought.

As you undoubtedly know, the State of New York is just commencing the construction of a barge canal, estimated to cost $101,000,000; the people of the state are about to vote upon a plan of issuing $50,000,000 worth of bonds for good roads—with the chances in favor of carrying the same; and the state is constructing a large number of buildings, such as armories, hospitals and schools. For all these projects the laboratory I represent tests the cement. Roughly we figure that during the next ten years, the barge canal will use an average of 350,000 barrels of cement per year, and the good roads will yearly average 140,000 barrels. The public buildings, constructed under the direction of the State Architect, will average about 25,000 barrels of cement each year. By testing a sample from every tenth barrel we will have to test over 50,000 samples each year.

In the case of extensive work by a corporation it is possible to specify a particular brand or brands. In the case of public work, as you know, the state cannot, or rather should not, specify brands so during the past five years we have tested 58 brands of cement; and each yearly average is about 32 brands.

The various contracts call for lots of cement ranging from 125,000 barrels to 100 barrels, but it is safe to say that the ordinary contractor on good-road work will buy his cement only as he has

immediate use for it. As a rule the smaller lots of cement are those with which we have the most trouble, inasmuch as the cement is frequently bought through small local dealers and is often cement which was never expected to be submitted for tests. We reject as much cement because of quick-setting as for any other cause, hence our interest in the subject of determining set and the conditions which influence the time of setting. We believe that no condition is of more interest than the question of normal consistency.

Our observations on this subject are drawn from our general experience and from a short series of tests made with the Vicat apparatus. These tests have been made since the speaker agreed to open this discussion, and were intended to definitely fix our conclusions.

These tests were conducted as follows:

The neat cement was gauged with the per cent. of water necessary to produce a paste of normal consistency according to our judgment of what it should be. The cement was thoroughly trowelled for about three minutes and then molded into a ball. This ball was then tossed ten times from hand to hand—the hands being held about six inches apart. Then the cement paste was placed in the mold, being pressed in by the thumbs in three layers, and struck off on the bottom with the trowel and then turned over and the top struck off. The molded cement was immediately placed under the plunger, or cylinder, of the Vicat apparatus. The plunger was gently placed upon the surface of the cement and then suddenly released. It was allowed to rest on the cement for ten minutes, which seemed to be the limit of time for penetration, for after that time in all cases no further penetration was evident. If the reading showed that the plunger had penetrated 10 m. m., or approximately 10 m. m., a similar trial was made with neat cement gauged with one per cent. more, and one per cent. less of water and penetrations noted.

If the plunger did not penetrate approximately the required 10 m. m. in the first trial, the percentages of water used in the second and third trials were selected accordingly. The idea was to obtain at least three tests—one at normal consistency according to the Vicat apparatus, and one test with a drier cement paste and one test with a wetter paste; and in connection with these trials was also noted the time of initial and hard setting of each paste.

The series covered 27 sets of trials and a total of 84 trial pastes. Twenty-five different samples of cement were used and they included 15 brands of cement. At least three degrees of consistency were made of each sample. The percentage of water required by Portland cements varied from 18 to 28, while the natural cements ranged from 26 to 34 per cent.

The results obtained were as varied as could be imagined. In practically all tests a depression was made by the plunger before any penetration took place, in fact, a clean cut penetration was the exception. Both depression and penetration were included in the reading as penetration.

It was almost impossible to obtain the exact percentage of water required to produce a penetration of the plunger to an even 10 m. m. There were so many influences in gauging and molding the paste that the best that could be done was to approximate the required penetration.

A literal interpretation of the paragraph on normal consistency in the recommendations of the Committee on Standard Tests for Cement would indicate that the ball of cement paste should be pressed directly into the mold—in fact some are so doing. All of our tests were molded as described, or as one would mold a neat briquette.

With some samples of cement the plunger would only slightly cut into the cement paste even though the consistency was considered as very wet. Where it was impossible to determine the consistency by the Vicat apparatus, because of this lack of penetration, the comparisons were made upon the judgment of the operator as to dry, normal and wet consistency.

In six sets of tests the penetrations did not differ more than 3 m. m. in all three trials, and at no time did one of these pastes show more than 5 m. m. in the reading. In one case in particular, the cement gave off water freely but the plunger would not penetrate more than the 5 m. m. just mentioned.

In regard to testing the consistency of neat cement by means of the Vicat apparatus our conclusion, confirmed by the series of tests, is this:

The Vicat apparatus is not satisfactory for all brands and samples of cement, inasmuch as it frequently fails to produce a required penetration of 10 m. m. unless the cement be almost

flooded by an excess of water. The method could perhaps be well recommended as a general aid to one not acquainted with the characteristics of the various brands, but it is hardly reliable enough to be used as the determining factor, in case of a dispute between laboratory and sales-agent, if the experience of the expert is pitted against the mechanism of the apparatus.

That the consistency of the cement paste, and the percentage of water used in gauging the paste has a very decided bearing on the time of setting is our experience.

We found in the series of tests just made, that even one per cent. of water will so effect the consistency that a quick-setting cement will fail to pass the requirements of the specifications for initial set, while one of the cements tested in this series was rejected by the State Architect because of the slow hard setting developed by having used the amount of water necessary to produce a consistency based upon the requirements of the Vicat needle apparatus.

The series of tests showed an influence of one per cent. of water to cause the initial set to vary from nothing to 183 per cent. in ordinary cases; while in one case it made a difference of 860 per cent. The average difference in time caused by one per cent. of water was about 25 per cent.

As a rule, the effect on hard set is not so great and yet a very soft consistency will often materially lengthen the time of setting.

As a bye statement we would say that we have found the tests for consistency a great aid in determining the brand of a cement which came to us unnamed; and also in proving that a cement claimed to be a certain brand was not the brand so claimed.

This question has been considered mainly from the view-point of the operator in the testing laboratory, whose duty, as inspector, is not to make samples of cement pass certain tests, but rather to detect any poor qualities which may be in the samples of cement submitted for inspection. For this reason, and because of the prospects of large work before us, we desire to definitely fix our method of determining normal consistency before there may be a disagreement between our laboratory and representatives of cement manufacturers over a case of time of setting. Judging from the past, this is possible, but it might not end as satisfactorily to both parties; so we are anxious to learn what the experiences of others may be.

DISCUSSION.

Mr. Humphrey.

MR. RICHARD L. HUMPHREY.—I should like to ask the author whether he found greater difficulty with natural or with Portland cement?

Mr. Greenman.

MR. R. S. GREENMAN.—The greater difficulty was found with Portland cement.

Mr. Humphrey.

MR. HUMPHREY.—As I understand your statements, you used as high as 24 per cent. of water for some of that cement?

Mr. Greenman.

MR. GREENMAN.—Yes; in one case 28 per cent.

Mr. Humphrey.

MR. HUMPHREY.—What was the normal?

Mr. Greenman.

MR. GREENMAN.—20 to 21 per cent.; 24 per cent. with a particular brand.

Mr. Humphrey.

MR. HUMPHREY.—How quick a setting cement was that?

Mr. Greenman.

MR. GREENMAN.—The cement averaged anywhere from two to three hours initial setting. It is a brand we get a great deal of, and with which we have trouble on this very point. That is a point which affects our laboratory very materially.

Mr. Humphrey.

MR. HUMPHREY.—Is that trouble also applicable to other cements than the particular brand referred to?

Mr. Greenman.

MR. GREENMAN.—Yes; we had trouble with six lots out of twenty-seven. The samples came to us in our routine line of work; they were not selected brands. Twenty-five samples tested were samples submitted to us in direct connection with work.

Mr. Humphrey.

MR. HUMPHREY.—I do not wish to speak for the Committee on Uniform Methods of Tests of Cement of the American Society of Civil Engineers, but, as a member of that committee, and as one who has had considerable experience with the selection of a method for determining the proper consistency of cement. A great deal of time has been devoted to this subject; it is an exceedingly difficult problem to devise a method for determining the normal consistency, such that any one, whether experienced in testing or not, can after reading the description obtain by the method anything like comparable results. All the methods that have heretofore been suggested have received careful consideration by

the Committee, and after a great deal of experimenting with the various methods it has decided on the Vicat plunger method as one which affords the best means for obtaining comparable and reliable results. The Committee does not contend that the Vicat method is a perfect one, for it realizes that it is far from such, but it is the best method that has thus far been proposed. The matter is open for suggestions, and it is hoped that some one will propose a method which will be free from the defects of the present method. In the meantime, in the absence of any better method, the Committee has adopted the Vicat method, and as far as its experience with investigators goes, reliable results can be obtained with it even by inexperienced operators. I should like to ask Mr. Greenman, since he has pointed out his objections to the method based on his own tests, whether he can suggest a better method for determining the normal consistency; and if not, whether in his judgment this method is not the best that has thus far been devised? **Mr. Humphrey.**

MR. L. C. SABIN.—I should like to repeat Mr. Humphrey's question, and ask what is there better than this test? I have not been a very ardent advocate of the Vicat method for determining consistency, and when I brought it before the Committee of the American Society of Civil Engineers, they said, "What do you want to do?" Possibly the French method for determining consistency, which is to make a ball and drop it from a given height, gives in the hands of some operators results which are more satisfactory to them. It is a question, however, whether it is best to make this the standard method to be used by everyone, and whether, in reality, better results can be obtained by it than by the use of the Vicat apparatus. **Mr. Sabin.**

The trouble which I think is inherent in the Vicat test is the point which Mr. Greenman has brought out—that the result depends upon the method of putting the mortar into the ring—and that, while in very moist mixtures you may get good results, yet in rather dry mixtures, which Mr. Greenman wished to use, you would not get good results. This seems to me to be the chief objection to this method—to say just how the mortar shall be put into the ring—but the progress report of the Committee of the American Society of Civil Engineers specifically states that it refers to wet mixtures, and while the investigator may wish to know how to determine for himself and how to tell other people what

Mr. Sabin. consistency he is using when manipulating dryer mixtures, yet so far as the report goes, it refers to the wet mixtures which are apt to be used in making other tests.

Mr. Aiken. MR. W. A. AIKEN.—As far as the Vicat apparatus is concerned, I think it is a good thing for inexperienced testers to use in testing a great many unknown brands of cement at one time. I do not know of anything better; but where there is a set of men handling a single brand of cement right along, they learn the peculiarities of that material, and in such a case I certainly would not use it, because it is too slow. As far as the percentage of water is concerned, I think it may be used to determine the normal consistency satisfactorily. What I call normal consistency is rather wetter, perhaps, than most people would use.

I think, however, that we should not knock a thing down, and say it is worthless, unless we have something better to put in its place.

Mr. Greenman. MR. GREENMAN.—It is not my intention to knock down something that has been put up, except in regard to this one particular point. I should like to state a particular case. We had a cement come in during the last two or three weeks which required, to get a penetration of 5 m.m., 3 per cent. more water than usual. Now, the water actually flowed out of the bottom of the mold and ran all over the glass. That cement was altogether too wet, yet you could not get a penetration of more than 5 m.m. That 's not right. Now, in such cases as that, should the experience of the operator determine what per cent. of water is to be used, or should we say positively that the Vicat apparatus shall be used, no matter how wet the cement might be?

Mr. Larned. MR. E. S. LARNED.—In referring to tests for normal consistency, I think the Committee in the recommendations made have plainly recognized the difficulties and variables connected with this test, and it does not appear to me to be reasonable to expect absolutely uniform results. The age of the cement, its degree of fineness, moisture contained and the operator himself, all have important influences upon the results. If the cement powder previous to this test was uniformly dried at the required temperature, using the cement that passed the 200 mesh sieve only, I believe results could be maintained within a narrower range of variation. The method and time of troweling, however, is a most important factor in this test, as it is in the tests for tension.

I believe the experienced and skilled operator can determine normal consistency without the assistance of the Vicat needle, but unfortunately we have too few operators of this character testing cement. **Mr. Larned.**

MR. HUMPHREY.—Mr. Greenman states that one of the samples of Portland cement that he tested generally required 24 per cent. of water for the normal consistency, and that with the Vicat apparatus it required 28 per cent. in order to get the proper penetration. It seems to me that this was a very abnormal cement and that 28 per cent. for a Portland cement would ordinarily make a very sloppy mixture. A normal Portland cement should not take more than 22 per cent. in order to secure a penetration of 10 m.m. with the Vicat needle apparatus, and it would seem to me that if a cement required from 24 to 28 per cent., an investigation should at once be made to determine whether it was not adulterated or in other respects abnormal. **Mr. Humphrey.**

When the Committee on Standard Specifications for Cement began the formulation of their rules, their first action was to adopt the Methods which had been reported by the Committee on Uniform methods of Test of Cement, and in order that they might test the value of these methods they sent five brands of Portland and four brands of natural cement to some thirty testing laboratories covering the most prominent in this country, but of varying degrees of experience. These samples were accompanied by the report of the Committee on Uniform Methods of Test of Cement, together with instructions as to the tests to be made.

A study of the results shows in general that while there was considerable variation in the results of the tests for tensile strength, time of setting and some of the other tests, the results as to the proper percentage of water required for each cement were concordant, the variation being hardly more than one-half per cent. These laboratories were scattered all over the country, and in most cases the operators had had no previous experience with the Vicat apparatus.

MR. GREENMAN.—I wish to state that the views I expressed are not my own views only, but represent the views of certain institutions of learning in our immediate vicinity, and also the views of certain cement manufacturers. **Mr. Greenman.**

ECONOMICAL MOLD FOR FORMING COMPRESSION TEST PIECES FOR CONCRETE.

By Clifford Richardson and C. N. Forrest.

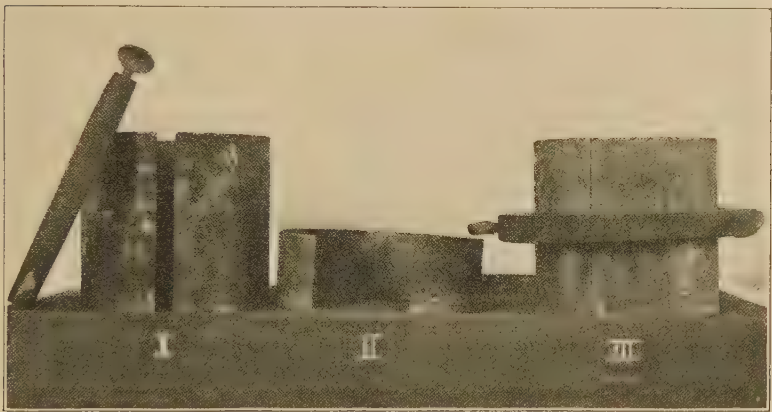
In the course of the initiation of an elaborate study of the effect of variation in the proportions and character of the materials entering into the composition of Portland cement concretes upon their s'rength, it was found that the purchase of a sufficient number of molds for the formation of cubes for the compression tests would involve a very large expense. One firm quoted \$11, another \$7 each for 12 six-inch cube molds with bottom plates. As these prices were practically prohibitive, recourse was made to the ingenuity of our machinist to supply the want and he has designed a mold which is not only cheap but more satisfactory than a mold for cubes for several reasons. The mold may be described as follows:

Tank steel $\frac{1}{8}$ in. in thickness is cut in strips 6 in. wide and 18.85 in. long. It is then rolled into a circular form until the two edges are brought together within $\frac{1}{2}$ in., as thown in illustration No. I. An iron ring is then cast 1 in. wide, $\frac{7}{8}$ in. thick and $6\frac{5}{8}$ in. in inside diameter. This is provided with two screws passing through it and o' sufficient length, when the ring is slipped over the tank steel cylinder, to compress it at such points as to bring together and close the opening which exists owing to the spring in the steel, in this way forming a closed mold which is ready for use. In order that the collar may always be applied longitudinally and the pressure produced evenly a cylinder of slightly larger diameter, as shown in illustration No II, is provided which shall hold the collar during compression parallel with the base. It has been suggested that two collars might serve more satisfactorily than one. The cost of such molds need not exceed \$16 to \$20 per dozen, ten made for us costing \$16.

The advantage of the mold is that the test pieces can be much more uniformly compressed than in the case of cubes where it is difficult to bring about thorough compression at the edges. That

this is the case is shown by the fracture of the cylinders. There is no wedging out of the sides of the test pieces and the fracture is a perpendicular one in contradistinction to the hour glass form which generally appears with cubes.

Mr. W. Purves Taylor has made some comparisons of the strength of cylinders as compared to cubes, on the same mortar, which shows that neat cement at 28 days gave an ultimate strength per square inch of 5,026 pounds for the former and 4,920 pounds for the latter, or a ratio of 1.022 in favor of the cylinder. In the case of a test piece made with a mortar consisting of 1 of cement



to 3 of sand the ratio was 1.133 in favor of the cylinder. On the addition of stone in various proportions the results obtained with the cylinder were not always as high as with the cube, but the average of all tests showed a ratio of .976 for the cylinder as compared with 1.0 for the cube. Mr. Taylor notes in many of these tests that the mortar was crumbly or soft. As the tests with neat cement and sand mortar without stone show a superiority in the strength of cylindrical test pieces the conclusion may be drawn that the cylindrical form is a satisfactory one. They also possess the great advantage that the test pieces can be used in a smaller machine than is required to break cubes six inches square.

LOW-PULLING EARLY-STAGE PORTLAND CEMENT *vs.* THE ORDINARY EARLY-STRENGTH DEVELOPING PRODUCT.

By W. A. Aiken.

The detailed strength requirements of the Standard Specification for Cement adopted by this society emphasized its recognition of the growing demand for a product of lower strength at early stage than has generally in the past been specified. The revolution in the engineering profession's views on this subject is in the author's opinion largely due to the general knowledge that the Board of Rapid Transit Railroad Commissioners of the City of New York was requiring such cement, which from the records of its Department of Inspection of Material continually showed its greater value from long time tests: the positive worth of such records being in the multitude of tests on such a large amount of material.

The following tables show average strengths at various periods up to 3 years of several classes of cement, involving over 1,250,000 barrels, inspected for the New York Subway construction. The classification fully and clearly impresses the value of our specification cement by showing test results on: (1) All accepted cement, this being arbitrarily divided into two classes—the first showing a neat strength less than 700 lbs. at 7 days and the second showing a neat strength more than 700 lbs. at 7 days; (2) Such cement as has been "turned over" to the manufacturer simply because the tensile strength was so high at 7 days as to render unlikely a satisfactory approximation to our specification gain requirement; (3) Such material as was absolutely "rejected" at 28-day period, solely for non-compliance with the gain requirement, which for the benefit of those not conversant therewith, is now stated to be 15 per cent. in neat briquettes and 25 per cent. in 2:1 sand mixtures, between 7 and 28-day periods. (4) Lastly for comparison, strikingly illustrating the age value of low early strength material, I give in Table I similar period averages for "accepted" natural cement used in certain parts of our work.

TABLE I.—SHOWING AVERAGE TENSILE STRENGTHS, AT VARIOUS AGES, OF NEAT AND SAND TESTS OF CEMENT FOR NEW YORK RAPID TRANSIT SUBWAY WORK.

	Neat Cement.								2: 1 Sand Mortar.						
	24 hrs. Lbs.	7 days. Lbs.	28 days Lbs.	3 mos. Lbs.	6 mos. Lbs.	1 yr. Lbs.	2 yrs. Lbs.	3 yrs. Lbs.	7 days. Lbs	28 days. Lbs.	3 mos. Lbs.	6 mos. Lbs.	1 yr. Lbs.	2 yrs. Lbs.	3 yrs. Lbs.
All "accepted" cement	300	689	799	799	799	805	791	759	404	525	568	549	552	523	492
"Accepted" cement pulling less than 700 lbs at 7 days	292	627	748	770	781	793	780	750	382	515	582	566	542	519	506
"Accepted" cement pulling more than 700 lbs. at 7 days	309	759	856	841	822	825	806	774	429	537	553	525	571	407	467
"Turned over" cement pulling too high at 7 days	337	857	907	863	831	844	688	...	460	518	474	409	384	...	..
"Rejected" cement, account poor gain at 28 days	327	757	792	812	804	807	767	722	434	519	538	511	508	505	520
For comparison "accepted" natural cement, 1 : 1	...	220	320	404	475	497	477	...	215	331	495	601	639	682	...

TABLE II.—SHOWING AVERAGE CHEMICAL ANALYSES OF CEMENTS INCLUDED IN TABLE I.

	Silica.	Alumina.	Iron.	Lime.	Magnesia.	Anhydrous Sul. Acid.
All accepted cement	20.92	8.53	2.78	63.05	2.38	1.61
"Accepted" cement pulling less than 700 lbs. at 7 days	21.07	8.59	2.80	62.83	2.33	1.69
"Accepted" cement pulling more than 700 lbs. at 7 days	20.76	8.46	2.76	63.28	2.42	1.58
"Turned-over" cement pulling too high at 7 days	20.05	8.10	2.80	64.18	2.45	1.55
Rejected cement, account poor gain at 28 days	20.52	8.62	2.81	63.21	2.35	1.81

Examination of these results shows very satisfactorily that al. our "accepted" cement, averaging as it does less than 700 lbsl tensile strength neat at 7 days, as specifically called for by the Pennsylvaina Railroad in that company's specifications for its New York-New Jersey Tunnel work, predicated upon previous years' showings of our tests as published yearly since the commencement of our work, corroborates the wisdom of our original requirements, that low-pulling early-stage cement showing a minimum gain of 15 per cent. in neat tests and 25 per cent. gain in sand tests at 28 days gives the best results thereafter.

The neat results of "All accepted" cement averaging at 7 days 689 lbs. and at 28 days 799 lbs. show a gain of 16 per cent. They continue to increase in strength at all periods, 3 months, 6 months and 1 year, with a slight loss of less than 2 per cent. at 2 years and some further loss at 3 years. The sand mixtures of this same "All accepted" cement averaging at 7 days 404 lbs. and at 28 days 525 lbs. show a gain of 30 per cent. These sand mixtures lose strength gradually after 3 months as is customary with at least all such Portland lean sand mixtures, though not till the 3-year period is reached does the strength fall below that at 28 days, and then very slightly.

Referring now to the subdivision of the "Accepted" cement, that showing neat strength at 7 days less than 700 lbs., actually 627 lbs., and at 28 days 748 lbs., giving a gain of 19 per cent.—gives greater percentages of improved strength with age, and while showing some loss as the original set of averages does at 2 year and 3 year period, is at latest date as strong as at 28 days. This cement's sand results, averaging at 7 days 382 lbs. and at 28 days 515 lbs., give a gain of 34.8 per cent. and hold up at end of 3 years better than any accepted averages.

Referring now to results of "Accepted" cement pulling over 700 lbs. neat at 7 days, actually 759 lbs., and at 28 days 826 lbs., and giving a gain of only 12.8 per cent.; this shows a persistent falling away in strength at all periods while its sand mixtures averaging at 7 days 429 lbs. and at 28 days 537 lbs., though meeting our specifications, giving 25.2 per cent., show at 2 years and beyond a marked decrease in strength both in comparison with its own previous periods, as well as with similar periods of other classes heretofore investigated.

Examination next shows that the "Turned Over" cement actually showed a gain in neat of only 5.8 per cent. and in sand mixtures only 12.6 per cent., with marked retrograde results at all periods after 28 days in both neat and sand averages, the last periods contrasting badly. The "Rejected" cement, comparatively a very small proportion of the total tested, since in this class is included only such material as was rejected simply on account of lack of gain, would indicate that the grading of material by its low tensile strength at 7 days, irrespective of any specified gain, would result (everything else being normal) in better product as shown from sand results, and these after all are the most important factors in determining a cement's value, than that high early stage strength cement so generally met with, since our tables show that the sand results of the "Rejected" cement, while not as good as those of the "Accepted" material, are much better than the "Turned Over" early high strength cement.

The ultimate value of low early stage cement is strikingly shown by the last line of averages, where the longest time results (though this sand mix is not of the same proportions as in the Portland cement) would indicate strongly the worth of early stage low pulling cement.

Nothing in the work of our department of inspection has yet shown anything to warrant the slightest recession from our original position, where the ruling first made from actual experience with some 100,000 barrels of accepted cement, corroborating our theory, resulted in the formal promulgation of our specification requirements for a percentage of strength increase.

That this gain called for should be obtained normally goes without saying, else any high pulling cement properly "doctored" with excess of water might be made sufficiently low pulling at an early stage as to give a required percentage of gain, but of course such material could not figure as naturally low strength cement, and from our records would not hold up in strength.

To conclude, it is interesting to compare the average analyses of the different classes of Portland cement given in Table II.

DISCUSSION.

Mr. Lesley.

MR. R. W. LESLEY.—Mr. Aiken's paper is a very interesting one on a subject that is new to many of us, and the figures which he gives, if the long time tests substantiate them, will certainly bear out his views and those of the Rapid Transit Commission upon cements showing an increase between the 7 and 28-day periods.

Mr. Aiken's paper, however, brings out something which, in the light of the great growth of the Portland cement industry and the numerous papers and tests upon this important building material, has been lost sight of, namely, the great value of the natural cements of the United States. Census figures show that the natural cement industry has existed in this country for many years, but within the last ten years has not been progressing as the Portland cement industry. Somehow it has been lost in the shuffle, and natural cement, which has in this country a wonderful record, has been in a measure lost sight of.

We must all remember that before Portland cement was manufactured here in such volume as to bring it within the reach of the average consumer, that our great country had many big buildings, many large stores, many bridges, many docks and many fortifications, all of which had been built with the old natural cements of the type of the Louisville, Rosendale, Utica, Cumberland and Lehigh. That these buildings are practically all standing, and that when any of them is torn down, the mortar is generally found to be stronger than the brick and stone of the various forms of construction is a well-known fact. The most interesting thing in connection with these mortars, which certainly the test of time has shown in the work where they have been used, is their gain in strength from the early inception of the setting operation and their continuing gain from year to year, and yet these cements were manufactured with antiquated machinery and in many cases under antiquated processes.

In connection with Mr. Aiken's paper which shows that an accepted natural cement, neat, at two years, gave results not very

Mr. Lesley.

TABLE I.

Summary of Tests of all Brands of Portland Cement, of which 900 Barrels or more were used on Construction Work by the Dam and Aqueduct and Reservoir Departments from 1896 to 1900, inclusive.

BRAND.	Composition of Briquettes.	TENSILE STRENGTH. Seven days.	Twenty-eight days.	One year.	Two years.	Three years.	Five years.	Seven and one-half yrs.	
		lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	
1. Atlas	Neat	677	719	803	813	814	794	1.034	1
	2 to 1	322	329	376	325	336	307	495	
2. Brooks-Shoobridge.	Neat	443	442	663	702	696	698	672	2
	2 to 1	255	311	444	447	449	443	448	
3. Giant............	Neat	448	483	561	622	618	633	727	3
	2 to 1	279	326	439	422	414	401	497	
4. Iron Clad	Neat	538	535	653	800	826	838	698	4
	2 to 1	308	354	454	394	378	369	378	
5. Stettin-Gristower..	Neat	570	596	677	714	709	695	684	5
	2 to 1	373	361	357	340	332	300	363	
6. West Kent	Neat	356	456	597	589	570	562	548	6
	2 to 1	261	326	455	434	424	391	409	
Total	Neat	518	559	669	707	701	702	686	
	2 to 1	292	333	415	389	389	365	424	

TABLE II.

Summary of Tests of all Brands of Natural Cement, of which 900 Barrels or more were used on Construction Work by the Dam and Aqueduct and Reservoir Departments from 1896 to 1900, inclusive.

BRAND.	Composition of Briquettes.	TENSILE STRENGTH. Seven days.	Twenty-eight days.	One year.	Two years.	Three years.	Five years.	Seven and one-half yrs.	
		lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	
1. Beach	Neat	136	223	430	467	482	506	462	1
	1 to 1	103	168	315	316	349	369	420	
2. Hoffman	Neat	130	204	433	467	495	514	468	2
	1 to 1	104	197	339	327	347	364	357	
3. Norton	Neat	128	202	403	440	456	479	452	3
	1 to 1	96	150	307	295	314	325	371	
4. Union	Neat	167	187	411	409	474	476	485	4
	1 to 1	156	206	512	570	617	576	551	
Total	Neat	131	201	420	456	480	501	465	
	1 to 1	102	181	365	338	352	363	405	

much below those of the accepted Portland cements pulling more than 700 pounds at 7 days, it may be noted that the curve of the accepted natural cements, at two years, shows none of the marked decreases that are shown in any of the curves of the Portland cements, whether accepted, turned over or rejected. This state of facts is even more marked in the case of a comparison of the natural cements, in sand mortar, when compared with sand mor- **Mr. Lesley.**

TABLE III.

Summary of Tests of Cement Used in the Construction of the Wachusett Dam and Other Works as the Wachusett's Reservoir of the Metropolitan Water Board, 1901 to 1904, *inclusive*.

BRAND.	Composition of Briquette.	TENSILE STRENGTH. 7 days lbs. per sq. in.	28 days lbs. per sq. in.	3 mos. lbs. per sq. in.	6 mos. lbs. per sq. in.	1 year lbs. per sq. in.	2 yrs. lbs. per sq. in.	
Portland Cement.								
1. Alpha	Neat	1,021	1.026	1,029	1,091	1,015	1,034	1
	2 to 1	474	428	445	405	406	320	
2. Alsen	Neat	776	753	761	834	813	824	2
	2 to 1	373	433	413	447	393	382	
3. Atlas	Neat	837	848	801	848	899	833	3
	2 to 1	384	450	444	445	422	393	
5. Giant	Neat	860	887	864	898	893	881	5
	2 to 1	403	450	455	450	435	408	
6. Helderberg	Neat	843	933	906	881	897	896	6
	2 to 1	301	409	377	380	386	372	
7. Iron Clad	Neat	700	712	714	788	807	851	7
	2 to 1	403	451	474	486	488	504	
8. Lehigh	Neat	871	879	897	907	898	1,050	8
	2 to 1	396	499	447	481	456	447	
Natural Cement								
Union	Neat	225	298	358	405	437	484	
	1 to 1	185	278	411	490	553	624	
	2 to 1	116	197	290	382	421	461	

tars of the Portland cements of all the grades referred to in the writer's paper. The natural cement was used in the proportions of one cement to one of sand, while the Portlands were used in the proportions of one of cement to two of sand, and the interesting fact is shown that while all the mortars of Portland cement show (whether accepted, turned over or rejected) decreases in sand mortars at some of the periods between seven days and three years,

Mr. Lesley. the natural cement in sand mortars shows a steadily rising curve. It is also to be noted that the natural cement at all periods beyond 28 days shows greater strength in sand mortars than neat.

If these records of Mr. Aiken's were the only recent ones upon the value of American natural cements, in sand mortars, it might be argued that the case was an exceptional one, but the Fourth Annual Report of the Metropolitan Water and Sewerage Board of Massachusetts, containing a summary of all tests of natural cement used on the Dam and Aqueduct Department of the Metropolitan Water Board, shows the interesting results upon natural and Portland cements appearing in Tables I and II.

In this case it will be seen that some of the natural cements, in sand mortars, were stronger than the Portlands at seven years, and practically showed very slight decreases in sand mortars as against the figures shown under similar conditions for the Portland cements.

The two-year records on the Wachusetts Dam (Table III), where some 175,000 barrels of natural cement were used, show that in the two to one mortars, the natural cements at the period named, were practically as strong as any of the Portland cements, and above the average of all the Portland cements used, and a comparison of the curves of the various brands will show again the fact that the natural cement shows no decrease in sand mortars, while all the Portlands show more or less fluctuation in the line between the 7-days and 2-year periods.

The above figures on the Boston Aqueduct and the New York Rapid Transit are again corroborated by an interesting statement in the shape of a Summary of Cement Tests on the New Croton Dam Division of the New York Aqueduct Commission representing a record of nearly half a million barrels of "Union" natural and "Giant" Portland cements used upon that important work. This summary covers all tests for a period of ten years, from 1894 to 1904, as follows:

TABLE IV.

CROTON AQUEDUCT.

"Giant" Portland Cement.

	7 days.	28 days.	1 yr.	2 yrs.	3 yrs.	4 yrs.	5 yrs.	6 yrs.	7 yrs.	8 yrs.	9 yrs.	10 yrs.
Neat	547	699	666	645	673	678	668	642	631	659	676	689
2 sand 1 cement	397	529	769	755	775	793	755	670	677	695	669	651

"*Union*" *Natural Cement.*

Mr. Lesley.

	7 days.	25 days.	1 yr.	2 yrs.	3 yrs.	4 yrs.	5 yrs.	6 yrs.	7 yrs.	8 yrs.	9 yrs.	10 yrs.
Neat	159	245	460	453	443	458	465	540	493	515	427	....
2 sand 1 cement	89	190	526	574	599	635	677	775	728	744	737	837

The interesting facts shown in the above table are, first, that in the Portland cement mortars, 2 to 1, the sand mixtures are practically at all times equal or above the neat breaking; second, but a more remarkable fact is that while the neat natural cement shows a line practically constant at long periods between 400 and 500 pounds, and always below the line of the neat Portlands, yet in the two to one sand mixtures, the natural cement at periods of over 4 years seems to gain upon the sand mixtures of the Portlands continuously, and at all times to exceed them, and when the long time period of 10 years is reached, there is nearly 25 per cent. greater strength in the natural than in the Portland sand mortars.

Similar results were obtained in the United States Engineer Office in the District of Columbia, where the following figures on 3 to 1 mixtures up to a period of 2 years, were shown:

TABLE V.

"*Union*" *Natural Cement.*

WHERE TESTED.	Mode of mixing.	One day. Average in pounds.	One wk. Average in pounds.	One mo. Average in pounds.	Three mos. Average in pounds.	Six mos. Average in pounds.	Nine mos. Average in pounds.	One yr. Average in pounds.	Two yrs. Average in pounds.
U. S. Engineers, District of Columbia, June, 1897 about 30,000 barrels	Neat	94	130						
	3 to 1	..	74	181	236	238	267	312	364

In this case a number of Portlands of both American and foreign manufacture were tested under the same conditions, and at the end of the 3-year period, the Portlands averaged 348¼ pounds in 3 to 1 sand mixtures, and the natural cement 344 pounds.

Mr. Lesley. Such figures as these are food for thought, and may lead to investigations into the causes underlying them. Certainly it cannot be denied that where large masses of masonry are to be laid in places where stability without immediate stresses is an element of construction, that the engineer would be well justified in increasing the amount of masonry by the use of the more economical natural cement, and thus obtain greater weight, greater strength and greater stability where the work is to endure, and where no great haste is required, and no immediate stresses are to be met.

Mr. Enright. BERNARD ENRIGHT (by letter).*—The data contained in Mr. Aiken's paper on "Low-Pulling Early-Stage Rotary Portland Cement *vs.* the Ordinary Early-Strength-Developing Product," are most valuable, and deserve the careful scrutiny of engineers and of all others interested in the manufacture, the testing, or the use of cement.

The ordinary testing of cement is seldom carried out for a greater period than 28 days, although some manufacturers test their product for periods up to a year or longer, which latter results, however, are seldom published. The article referred to contains tests up to three years, and is particularly important in throwing light on the working of the specification requiring a certain percentage of increase in strength of 28-day tests over 7-day tests. The advisability of inserting or insisting upon such a specification has long been a question of decided difference of opinion between the manufacturer and the consumer of cement, and yet there has been a dearth of published information in regard to the subsequent behavior of cement condemned on account of failure to meet this percentage of strength increase requirement.

The tests published in Mr. Aiken's article are valuable, not only for their comprehensiveness, but because of their source; they were made, not by a manufacturer of any particular brand of cement, but in the laboratory of a consumer, under specifications requiring a minimum increase of 15 per cent. in neat strength and 25 per cent. in sand strength, in 28-day tests over 7-day tests, the inspection involving several different brands for a total of 1,500,000 barrels.

Figures, especially when obtained under such conditions, are bound to carry most decided weight, not only because of the long-

* This and the following discussions were elicited by a reprint of Mr. Aiken's paper in the *Engineering News*, and were first published in that journal.

Mr. Enright.

time periods involved, but also because of the vast number of tests made on the enormous bulk of material examined. An examination of the data presented in the article reveals the most positive evidence yet presented of the injustice which actually resulted in these cases, and is likely to result in all cases, by an adherence to the "percentage of strength increase" specification quoted.

Cement in work is, of course, never used neat, the behavior with sand being the only true criterion of what can be expected of the cement in actual work; in fact, Mr. Aiken, himself, in the course of the same article, refers to "sand results, which after all, are the most important factors in determining a cement's value."

Quoting from the article, the summary of all the accepted and all the rejected cement of these 1,500,000 barrels, gives results as follows:

Long Time Test of 1:2 Portland Cement Mortars.

	7 days.	28 days.	3 mos.	6 mos.	1 year.	2 years.	3 years.
All accepted cement, lbs	404	525	568	549	552	523	492
Cement rejected for poor gain at 28 days, lbs...	434	519	538	511	508	505	520

These figures show conclusively that the "percentage of strength increase" specification resulted in rejecting first-class material—better cement, in fact, than that accepted, the strength of the rejected cement at the end of three years being 28 lbs. greater than the strength of that accepted. The cement accepted showed the decided falling off, at the end of three years, of 33 lbs. from its strength at 28 days, which latter strength in a manner controlled its acceptance, while the cement which was rejected showed no falling off at the end of three years, in fact recorded a slight increase. Reduced to percentage, the accepted cement, while making its required increase of 25 per cent. in the short time period of 28 days, lost 6.3 per cent. of this strength at the end of three years; the rejected cement, while failing to make the required 25 per cent. increase in the short time period of 28 days registered a small percentage gain at the end of three years and was then about 6 per cent stronger than the accepted material. After the three-month period, the maximum falling off in strength of the rejected material

Mr. Enright. at any time during the entire three years was only 33 pounds while the accepted cement during the same period showed a maximum falling off in strength of considerably more than twice this, or 76 pounds.

The publication of comprehensive data of this kind, covering as it does thousands of tests, and the careful analysis of the figures recorded, cannot fail eventually to impress engineers with the fallacy of the conclusions sometimes drawn from the comparison of strength tests at the 28 days and the 7 days periods.

Mr. Lewis. F. H. LEWIS (by letter).—Mr. Aiken's paper on "Low-Strength Portland Cement" having been printed in a number of the leading engineering journals, has been very widely read and will receive from engineers the consideration which it undoubtedly deserves. As a paper before the Society for Testing Materials, nearly all of whose members are very familiar with the phenomena of hardening in cements, the paper deals quite sufficiently with the data, but to many engineers who have not had, and who cannot have, an opportunity for looking into the details of cement testing, I believe further comment would be acceptable. Mr. Aiken, of course, knows that he is recording purely conventional tests whose bearing on the mechanical and chemical changes which are going on in the cement he does not take the trouble to explain; and they require some explanation.

1. Portland cement is a highly sensitive chemical compound, essentially the same in all cases, but considerably affected in its quality by accidental variations:

a. In chemical composition.

b. By methods of manufacture and storage and especially the effects of moisture taken up in various ways.

c. By the mechanical manipulation to which it is subjected.

Cements will always show very considerable variations in results both in strength and in hardening activity, due entirely to the effects of these accidental causes.

2. The hardening of cement is essentially a process of crystallization or induration by the formation of crystals. A sound cement, treated with water, gets hard and stays hard. This is all we expect of it. This does not necessarily mean that it shall develop increasing tensile strength with time. It does not mean that it should develop increasing crushing strength. I hold,

therefore, that long-time tests for tension alone are of no value unless they are supplemented by compression tests. In the formation of a crystalline body two things occur: one is, the formation of crystals and the other is the formation of lines of cleavage (which are lines of weakness) between the crystals. In this regard hardened cement is quite comparable to cast iron, having a high compression strength due to the hardness of its crystals, and a low tensile strength due to the weakness of their union. **Mr. Lewis.**

It is necessary, therefore, to point out emphatically that the loss of tensile strength in briquettes after twenty-eight days is quite a normal occurrence, established through a very long series of tests by many observers. It generally indicates merely a hardening of the crystals, and must not be regarded *per se* as an indication of poor quality. I have just been examining a table of long-time results of Portland cement published by the late Prof. Tetmajer, of the Zurich Polytechnic Institute. These results extend to one or two years and give both tensile and compression tests of the samples submitted. About one-half the samples show a decrease in tensile strength at some stage of hardening. In compression tests, however, all these specimens show progressive gains with age throughout the table. I am compelled to refer to European tests for this information, because there are very few compression tests on record in this country.

Two things will suggest themselves to anyone who examines Mr. Aiken's table, to wit:

1. He has reasonably established the correctness of his views in the case of the "Turned-over Cements."

2. He has failed to establish the correctness of his rulings in the case of the "Rejected Cements."

All things considered, the series of tests obtained from the Rejected Cements is as good as any tests he reports. It is not unfair, therefore, to hold that Mr. Aiken's idea is correct, but his method of carrying it out is not satisfactory. A cement with too great chemical activity, too much "fire" in it, has been found objectionable in many series of tests and has indeed been known, in long-time tests, to show very much worse results than anything which Mr. Aiken records. I admit that it is important to rule this cement out by proper specifications, but I consider that these specifications should reasonably recognize the variations in tests

Mr. Lewis. due to accidental causes and the fact that a progressive increase in tensile strength is not normal.

I do not know that I am prepared to offer a specification to cover this point. I am in sympathy with ruling out cements that still have "fire" in them, but I am satisfied, other things being normal, that cement which will show 700 pounds tensile strength in seven days and 800 pounds at twenty-eight days is better than one that shows 400 pounds in seven days and 500 pounds in twenty-eight days. Under the specifications of the Rapid Transit Bureau the latter would be accepted and the former rejected. The difference between the two is due to a small difference in chemical composition. Possibly one-half per cent. in lime would make this difference in tensile strength at seven days, and in some cases this small difference of one-half per cent. in lime would be important to the manufacturer for other reasons. His formula might be a narrow one, requiring the lime to be at or near certain figures. To reject this cement would be a hardship. One of the best plants in the Lehigh Valley district makes cement with this peculiarity. It is really of superior quality, a fact which has been demonstrated during a manufacture of ten or twelve years.

Other things being equal, and within certain limits, we want cement which will attain early strength. It suits modern conditions. Portland cement has displaced natural cement because, while they may be equally hard at the end of a year, Portland cement gets hard rapidly and permits of continuous work.

My suggestion is that the clause in regard to the increase in strength at twenty-eight days should read so that it might, or might not, call for rejection at the option of the engineer. This would enable an inspector to exercise discretion with different manufacturers using somewhat different formulas, and to recognize accidental variations in his tests. There should be no difficulty in establishing what tests are normal for any brand of cement and dealing with it accordingly.

Mr. Hartranft. W. G. HARTRANFT (by letter).—To show the extent of the injustice sometimes done cement manufacturers by specifications containing clauses requiring certain percentages of increase between the 7- and 28-day tests, I submit to you a copy of the tests furnished the manufacturer by the inspector on three cars of Old Dominion Portland cement which was supplied under

the specifications quoted further on, and which was rejected for failing to meet the specifications in regard to increase in strength between the 7- and 28-day tests. Tests reported as follows: Mr. Hartranft.

Consignment.	1.	2.	3.
Per cent. passing 100 sieve	94.2	95	95.1
Per cent. passing 200 sieve	75.4	75.1	74.9
Set. light wire, in hours	2¼	2¼	3
Set. heavy wire in hours	4¾	4¾	5
Soundness, air test	O.K.	O.K.	O.K.
Soundness, cold water test	O.K.	O.K.	O.K.
Soundness, boiling water test	O.K.	O.K.	O.K.
Strength, neat, one day, lbs. sq. in	345	487	416
Strength, neat, 7 days, lbs. sq. in.	730	749	663
Strength, neat, 28 days, lbs. sq. in.	744	772	716
Strength, 1: 3 mortar, 7 days, lbs. sq. in.	217	216	228
Strength, 1: 3 mortar, 28 days, lbs. sq. in.	299	359	425

The specifications governing cement used on this work required the cement to be sound in hot and cold water, to show a fineness of 92 per cent. on a No. 100 sieve and 75 per cent. on a No. 200 sieve, not to show initial set under 45 minutes, nor final set over eight hours, and tensile strength as follows:

Neat Cement:	*lbs.*
After 24 hours in air	200
After one day in air and 6 days in water	450
After one day in air and 27 days in water	600

The 7-day test shall show an increase of at least 50 per cent. in strength over the 1-day test and the 28-day test an increase of at least 25 per cent. in strength over the 7-day test.

Mortar Briquettes:	*lbs.*
After one day in air and 6 days in water	150
After one day in air and 27 days in water	225

The 28-day test shall show an increase of at least 30 per cent. in strength over the 7-day test.

Five briquettes shall be broken for each test and the average of the three highest considered as the strength of the cement.

Notes.—The neat tests are of less value than those of the briquettes made with sand and cement. The fineness of the cement is important, for the finer it is the more sand can be used with it.

Mr. Hartranft. It will be seen the tests on the three cars given above that the cement met the tests for fineness, soundness and set, and that all the neat tests showed a greater strength at 7 days than was required at 28 days and yet continued to harden up to the 28th day point although not showing the 25 per cent. increase. On the other hand, the sand briquettes met the 7-day tests and showed an increase of 33 per cent., 66 per cent. and 86 per cent., respectively, yet the cement was rejected. As it was impossible for anybody to furnish a better grade of cement, the manufacturers of Old Dominion Portland cement refused to supply any further cement on the work subject to the interpretation of the specifications by the inspector.

The note at the bottom of the specifications, stating that the neat tests were of less value than the sand tests, would appear to have been placed in the specifications in order that the engineer could use his discretion in accepting the cement if it failed to meet the neat tests after having met the sand tests, yet it did not save the cement from rejection in this particular case. The suggestion made by Mr. F. H. Lewis, in his discussion of Mr. Aiken's paper, for specifications to be drawn giving the engineer the option of rejecting cement for failure to show the increase between the 7- and 28-day tests, or not, as he saw fit, would not have helped the matter out in this case.

The writer would like to be informed by Mr. Aiken whether the Rapid Transit Bureau would reject cement for failing to show 15 per cent. increase on the neat briquettes from 7 to 28 days, provided the cement had exceeded this requirement on the sand tests.

Mr. Aiken. MR. W. A. AIKEN (by letter).—Referring to the discussion of Mr. Bernard Enright and Mr. F. H. Lewis, the following comments seem appropriate:

The good final showing of the tests on "Rejected" material in my tables loses much of its weight when my remarks thereon are noted; namely, that this cement represented "comparatively a very small proportion of the total tested," and "would indicate that the grading of material by its low tensile strength at seven days, irrespective of any specified gain, would result (everything else being normal) in better product than that high early stage strength cement so generally met with."

The manufacturing contracting company for the cement used on the New York Rapid Transit work, and myself, have always agreed, that while it is possible under our specification and system of inspection that some good material may have been rejected, viz., this very small percentage of the whole, whose records your two correspondents make too much of in comparison with the large volume of records on the balance of material, we are both quite sure no bad cement has been accepted; though more or less of this accepted material has in some instances closely approached the actual minimum limit of our requirements, and showed up satisfactorily in the long run, quite contrary to Mr. Lewis' assertion, that such material is not as good as the higher pulling cement. **Mr. Aiken.**

No one is readier to admit than myself that tensile tests are not the ideal ones, especially for long time results, where the crystalline character of the formed product of the briquettes tested may very easily influence results. For that very reason the comparatively few tests on our rejected material, which on their face at the last period show slightly better than the accepted material record should have very little weight against the infinitely larger number making up these latter records, which do show best at all periods, except the very last three years, and then with only a difference of 28 pounds in favor of rejected material. It is certainly not my opinion that, as stated by Mr. Lewis, the better material attains its strength comparatively early; this retrogrades as shown.

The Board of Rapid Transit Railroad Commissioners of the City of New York through its Department of Inspection of Material, acting for its Chief Engineer, certainly see no reason to warrant the slightest recession from their original position, "That low-pulling early-stage Portland cement, showing a minimum gain in both neat and sand between seven days and twenty-eight days," is the best material.

Referring to Mr. W. G. Hartranft's specific inquiry as to whether I would accept cement failing to show 15 per cent. increase in the neat briquettes from 7 to 28 days, provided the cement had exceeded this requirement in the sand tests. I *have* accepted more or less material generally described but with this distinction, that the sand gains must *not* be abnormal. In other words, I might easily accept material showing only 10 per cent. gain neat and from 20 to 30 per cent. in sand, while I would not accept

Mr. Aiken. material failing similarly neat but gaining 40 to 60 per cent. in sand. Our records show this class of products retrogrades bodily. The differentiation between inspection and testing is marked by the exercise of discretion. Hard and fast requirements should be issued only as a protection. The aim of our gain clause is to rule out material of too great chemical activity, even though at the expense, possibly, of a small amount of material, while at some later date, than the time limit when action *must* be taken, shows itself of a value equal to regularly accepted material. We try to avoid accepting any bad material even at the risk of rejecting some little that may be good.

INVESTIGATION OF THE EFFECT OF HEAT UPON THE CRUSHING STRENGTH AND ELASTIC PROPERTIES OF CONCRETE.

By Ira H. Woolson.

It is well known that concrete in a building construction will withstand the attack of a fierce conflagration for some hours and retain its stability of form and strength. This has been proven by actual fires in buildings, and repeated severe fire tests upon full-sized floor units and partitions. It is also well known that concrete constructions have occasionally failed during conflagration and during official fire tests being made to determine the efficiency of some particular method of reinforcement. The causes of these failures were not always well defined. Usually they have been directly traceable to defective metal protection, unwise design of structural parts, or to the fact that the concrete was too green when subjected to the test. In some cases, however, the cause of failure was not entirely clear and much speculation has been rife as to just what degree of heat a concrete would stand before its strength and elasticity would be affected. This study was undertaken as an effort to throw some light upon this interesting subject.

The first step was to ascertain what previous work had already been done along the same line and the result obtained. A careful examination of the transactions of the engineering and scientific societies and the leading American technical journals for several years back furnishes very meager information.

The fire tests of reinforced concrete, such as have been conducted by the British Fire Prevention Committee in London, and by the writer in co-operation with the Bureau of Buildings in New York City and elsewhere, have for their purpose the determination of three properties: 1st, effect of a continuous fire at 1,700° or 2,000° F., for three or four hours; 2d, effect of the application of a strong stream of water at short range while the material is still at a high temperature; 3d, amount of deflection due to a load during the fire, and subsequent increased loading to 600 lbs. per

sq. ft. after the structure has cooled. The methods of construction and character of test are regulated by municipal specifications in this country, and by rules of the British Fire Prevention Committee in England.

The concretes used have included trap, limestone and cinder, and were usually 1-2-4 or 1-2-5 mixtures. The reports of numerous tests of this character were examined and in most instances the concrete stood the heat and subsequent loading well, but the results were general and referred to the quality or resistance of a particular construction rather than to specific data regarding the concrete itself. Large numbers of tests of compressive strength and elastic properties have been made upon concrete of various composition and after different preliminary treatments, but no records were found in which the concrete was heated prior to testing.

The report of the U. S. Arsenal at Watertown, Mass., for 1902, contains data of tests of neat cement cubes of several brands, which were heated before crushing. A synopsis and discussion of these is given by James E. Howard in the May, 1905, issue of "Cement," and some of his conclusions are given, since it is fair to assume that the action of neat cement under heat should be at least a slight criterion of that of concrete. The following is a summary of the results reported by Mr. Howard.

TABLE I.—EFFECT OF PREVIOUS HEATING ON CRUSHING STRENGTH OF NEAT CEMENT AND 1:1 SAND MORTAR.

(Watertown Arsenal, 1902. J. E. Howard.)

Composition.		Not Heated.	Ultimate Crushing Strength in lbs. per sq. in After Heating.							
Cement.	Sand.									
Temperature F.	..	......	200°	300°	400°	500°	600°	700°	800°	900°
1 Alpha*	..	9167	8830	7920	9190	9400	9333	8217	8060	6060
1 Alpha†	..	12480	14447	13767	13910	12787	12130	12130	9985	....
1 Dyckerhof* ..	..	5017	....	....	....	....	4313	3483	4280	....
1 Mankato* ...	..	1867	1657	1876	1966	1603	1453	1496	1400	1185
1 Mankato†....	..	3873	4043	3523	3810	4133	4133	3957	3900	2990
1 Mankato*....	1	538	491	432	....	471	....	381	....	317
1 Mankato†....	1	2170	2067	1953	....	2063	....	2240	....	1767

* Cubes set in air. † Cubes set in water.

It was desired to ascertain the effect of elevation of temperature alone without introducing internal strains incident to a state of unequal temperatures in different parts of the specimen. The test pieces were 4-in. cubes cast slightly more than a year previous. Tests were at intervals

of from 4 days to 4 months after heating. The cubes were gradually raised to the recorded temperatures. The heating took one hour, the maximum temperature was held one hour, and the specimens were then allowed to cool slowly in dry sawdust or powdered asbestos. During the heating the specimens developed fine cracks; these were hardly visible immediately after cooling nor were they one day later. Four days after heating they were generally developed and at eleven days they were nearly at a maximum. The effect upon the crushing strength was not serious when the cracks were fine, as the parts fitted together under pressure.

Table I shows the variation in ultimate crushing strength of the cubes. Each result is an average of three tests. This indicates that there is no decrease in strength up to a temperature of 600° Fahrenheit, but for higher temperatures the strength diminishes quite rapidly.

A search for previous similar investigations was so fruitless, i was evident that our explorations were to be conducted in practically an untrodden field, so the method of procedure was the next consideration, the desire being to make the conditions conform as nearly as possible to practice.

Since all the factors which enter the concrete problem are variables, it is extremely difficult to arrive at even a partial solution under any one set of conditions. There is, first, variation in the quality of the cement; second, difference in size, sharpness and cleanness of the sand; third, size and quality of the stone, gravel, slag or cinders used; fourth, variations in the proportions of the three solid ingredients and the amount of water used, and, fifth, method of mixing and treatment after molding, including age before testing. This latter is quite important, for it is well known that the strength of concrete increases rapidly for a period of six to twelve months after casting and continues to increase slightly up to two or more years.

It was decided to make the concrete a 1-2-4 mixture of cement, sand and $\frac{3}{4}$-inch broken stone, this being a common mixture used in constructing reinforced concrete floors. The cement was supplied by your Committee on Concrete and consisted of a mixture of different brands of the best grades of Portland. The sand was taken from a quantity being used in the erection of a new building on the University grounds. It was of medium size (90 per cent. passing a 12-mesh sieve), fair quality, and not especially clean. Two varieties of stone were employed, Hudson River blue limestone and Hudson River trap-rock. Two sets of specimens were prepared which were duplicates in every respect, except that one contained limestone and the other trap-rock.

The mixing and casting were done by a laborer familiar with concrete work. A moderately wet mixture was used, tamping in the molds being continued until the surface of the concrete became flushed with water.

The investigation had three primary objects. First, to ascertain at what temperature the concrete began to lose crushing strength due to heat treatment; second, the rate at which strength decreased as a result of increase of heat, and last, but not least, the effect of varying temperatures upon the elastic properties of the concrete; the purpose being to determine if the elasticity began to diminish prior to the strength or concurrently with it. It was decided to make 500° F. the initial heat, and then to increase the temperature by intervals of 250° F. to 2,250° F., testing specimens at each temperature. The upper temperature limit was well above the average of a burning building, which is conservatively estimated by most experts as ranging from 1,500° to 2,000° F.

The determinations of crushing strengths were made upon 4-inch cubes; for the elastic properties, prisms 6x6x14 inches, were used, the height being sufficient to allow the measuring of compression on a length of 12 inches, and the cross-section being large enough to avoid the necessity of considering the specimen as a column.

To establish the quality of the concrete, three cubes and three prisms of each composition were first tested without being heated; then three cubes and two prisms of each composition were tested at each temperature.

Method of Heating.—The heating to 1,750° F. was done in an oven type of gas furnace. The furnace had a capacity of twelve cubes or two prisms and also allowed room for protecting them from the flames with fire bricks placed around the sides and top. The specimens were kept from contact with the floor by being supported on iron rods. Above 1,750° F. the heating was done in a large gas crucible furnace.

To insure equal heating throughout the specimen, the rate of heating was arbitrarily fixed at 45 minutes to reach the first 500°, and 30 minutes for each successive 250°, the maximum heat being held 10 minutes before removing the specimen. This method subjected the prisms to a shorter period of heating than the cubes for every temperature except 500°, because the former were brought to

the required temperature, held there, and then removed. The latter were charged into the furnace 12 at a time, brought to the proper heat, held there 10 minutes, and three cubes removed; then the temperature was raised 250°, and held again. This being continued until the last cubes were removed. Good results were

TABLE II.—COMPRESSIVE STRENGTH OF 4-INCH TRAP-ROCK CONCRETE CUBES.

Specimen No.	Age in Days. Before Heating.	Age in Days. Between Heating and Testing.	Heated to Degrees F.	Ultimate Strength lbs. per sq. in.	Condition after Heating.
1....	32	....	Unheated	1903	
2....	32	....	"	1913	
3....	32	....	"	1892	
4....	36	2	500	1808	
5....	36	2	500	2100	
6....	36	2	500	1853	
7....	36	2	750	1880	
8....	36	2	750	1690	Slight cracks.
9....	36	2	750	1950	
10....	36	2	1000	1547	Brittle and full of minute cracks.
11....	36	2	1000	1273	Same.
12....	36	2	1000	1418	Same.
13....	36	2	1250	1110	Brittle and had several small cracks.
14....	36	2	1250	1163	Same.
15....	36	2	1250	1459	Same
16....	50	10	1500	1265	Few cracks; appears sound.
17....	50	10	1500	1802	Sound; no cracks.
18....	50	10	1500	1602	Same.
19....	50	10	1750	644	Full of cracks.
20....	50	10	1750	1220	Same; one crack extending entirely around.
21....	50	10	1750	904	Full of cracks.
22....	44	9	2000	680	Full of cracks; one extending around 3 sides.
23....	44	9	2000	1072	Few cracks; surface was pitted.
24....	44	9	2000	790	Same.
25....	44	9	2250	458	Slightly fused on one edge; few cracks.
26....	44	9	2250	626	Very much fused on bottom.
27....	44	9	2250	420	Full of cracks; slightly fused on one edge.

obtained for the cubes for all temperatures, but it is doubtful if the prisms were uniformly heated at temperatures under 1,250°, as will be explained later.

Temperatures were measured continuously by a Le Chatelier pyrometer. The thermo-couple was located about 4 inches above the floor of the furnace and closely surrounded by the specimens.

After heating, the specimens were immediately removed from the furnace and allowed to cool in the air. The testing was done at intervals up to three weeks subsequent to the heating.

Method of Testing.—The tests were made upon a Riehlé testing machine of 100,000 pounds capacity. The cubes were faced on the upper surface with plaster of paris, the lower face being in

TABLE III.—COMPRESSIVE STRENGTH OF 4-INCH LIMESTONE CONCRETE CUBES.

Specimen No.	Age in Days.		Heated to Degrees F.	Ultimate Strength lbs. per sq. in.	Condition after Heating
	Before Heating	Between Heating and Testing.			
1....	34	....	Unheated	1968	
2....	34	....	"	1843	
3....	34	....	"	1640	
4....	38	3	500	1227	Somewhat brittle.
5....	38	3	500	1290	Same.
6....	38	3	500	1184	Same.
7....	38	3	750	1122	Brittle, and gave metallic sound if struck.
8....	38	3	750	1440	Same.
9....	38	3	750	1170	Same.
10....	38	3	1000	923	Stone slightly calcined.
11....	38	3	1000	991	Same.
12....	38	3	1000	1214	Same.
13....	38	3	1250	988	Clacination throughout.
14....	38	3	1250	1038	Same, but appeared sound.
15....	38	3	1250	903	Same, surface discolored.
16....	44	3	1500	680	Same, edges chipped.
17....	44	3	1500	778	Same, full of small cracks.
18....	44	3	1500	838	Same, crumbles easily.
19....	44	3	1750	832	Same, and discolored.
20....	44	3	1750	684	Very fragile.
21....	44	3	1750	922	
22....	44	3	2000	...	Crumbled on cooling.
23....	44	3	2000	...	Same.
24....	44	3	2000	...	Same.
25....	44	3	2250	...	Same.
26....	44	3	2250	...	Same.
27....	44	3	2250	...	Same.

all cases smooth enough to require only a few sheets of blotting paper to insure a firm bearing. The pressure was applied to the top and bottom faces as determined by their position in the mold. The pressure was applied very slowly and steadily until the specimen failed.

The prisms were faced on both ends with plaster and compressions measured on a gaged length of 12 inches by an electric

contact extensometer adjusted to the specimen as shown in Fig. 1.* The load was applied at the same rate as for the cubes. It is important that the load should not be applied faster than the concrete will adjust itself to the new stresses, or a fictitious strength

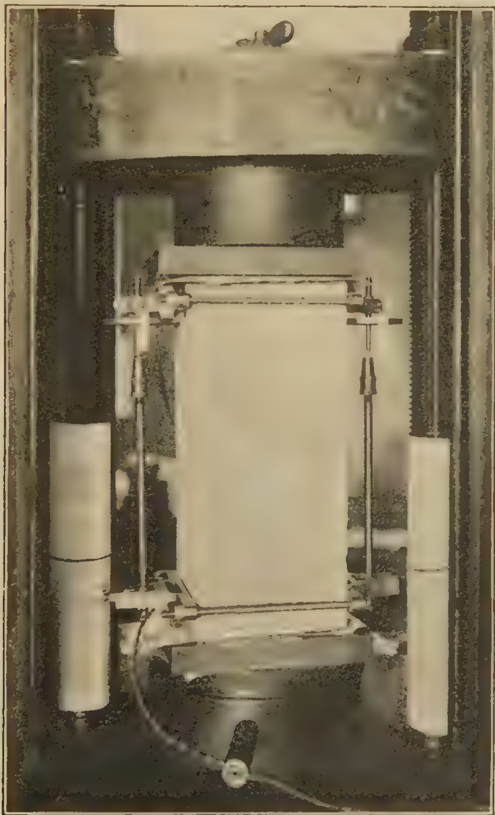


FIG. 1.

will be recorded and instrument readings will alter until an equilibrium has been established. Compressions were measured at loads of 0, 25, 50 and 100 pounds per square inch, and then by increments of 200 pounds per square inch, until indications of failure

* Acknowledgment is made to the Engineering News Publishing Company for the cuts used in this paper.

forced the removal of the instrument. Sets were measured one minute after the removal of each load, this interval being found sufficient to allow the specimen to assume a stable condition.

It was originally intended to have the concrete at least sixty days old before testing, but owing to an unavoidable delay in securing part of the material it became necessary to test the specimens

TABLE IV.—COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY OF TRAP-ROCK CONCRETE PRISMS.

Specimen No.	Age in Days. Before Heating.	Age in Days. Between Heating and Testing.	Heated to	Ultimate Strength in lbs. per sq. in.	E at 200 lbs. per sq. in.	E at 600 lbs per sq. in.	E at 1,000 lbs. per sq. in.	Condition after Heating.	Specimen No.
2 ..	33	....	...	1,560	3,450,000	2,140,000	1,700,000	Specimen in good condition	2
3....	33	....	...	1,820	3,180,000	3,000 000	2,440,000	Same	3
4....	34	....	...	1,725	3,340,000	2,070,000	1,610,000	Same	4
10A ..	48	6	500°F.	1,404	715,000	902,000	863,000	Same	10A
11A ..	48	6	500°	1 970	834,000	950,000	1,040,000	Same	11A
12B ..	49	3	750°	1,250	490,000	526,000	472,000	Very minute cracks apparent	12B
13B ..	49	3	750°	835	400,000	461,000	......	Appeared sound, but brittle.....	13B
16C ..	50	5	1,000°	735	128,000	171,500	......	Same, had a metallic ring when struck.....	16C
17C ..	50	5	1,000°	1,100	160,000	212,000	......	Same	17C
20D ..	54	3	1,250°	910	89,000	122,000	......	Surface covered with small cracks	20D
21D ..	54	3	1,250°	1,055	83,000	125,000	......	Same	21D
24E ..	56	9	1,500°	250	19,400	......		Very bad specimen, sides warped and shattered ..	24E
25E ..	56	9	1,500°	...	......	......	......	Worse than 24E.......	25E

when a little over a month old. This was much to the disadvantage of the concrete in the fire tests, and it also accounts for the rather low values obtained in the tests of unheated specimens.

Results.—Table II. gives the ultimate crushing strength of the 4-inch trap cubes which were heated to various temperatures and crushed after cooling. No appreciable effect upon the strength can be noted until a temperature of 750° is reached. This gave

slightly lower average strengths. Beyond 750° the decrease was marked, though there were two or three exceptions to the rule notable at 1,500°, where two of the specimens gave remarkably high results. Why these cubes should have withstood the heat so much better than the others is not known. With the above excepttion, the surface of all specimens heated over 750° was covered with minute cracks. At 2,250° F. the cubes were slightly fused, due to the fact that fire-brick protection was displaced in removing previous specimens, and the remainder were more or less exposed to direct contact with the flames.

FIG. 2.—Appearance of 4-in. Cubes of Limestone Concrete Three Days After Heating to Temperature of 2,000–2,250° F.

Table III. gives similar data for the limestone cubes. The three unheated cubes show an average strength only slightly inferior to that of the trap mixture. Heating to 500°, however, gave a great loss in strength. There were no evidences in the appearance of the cubes indicating this deterioration. No further weakness resulted at a temperature of 750°, but beyond this the loss of strength continued. After heating to 2,000° and 2,250° the cubes appeared strong and in good condition while hot, but when cold they began

to disintegrate, and at the end of three days their appearance was as shown in Fig. 2. No attempt was made to test these specimens.

Table IV. contains the results of the test upon the elastic properties of trap-rock prisms. Three curves were also plotted for each specimen: 1, total deformation; 2, set; and 3, true elastic. The latter was obtained by Professor Bach's method, viz., by subtracting from each total deformation reading the corresponding set reading. Modulus of elasticity (E) was figured for three points of the true elastic curve.

Taking the age into consideration the values for the unheated specimens compare favorably with the results of other investigators. As is usual, the value of E diminishes with increase of pressure. With the heated specimens this is not so marked; in fact, it is often the reverse, particularly with the intermediate loading. There is, however, a very marked decrease in the value of E due to the heating. This change becomes very apparent even with a temperature of 500° and the value gradually decreases with the increase of heat. There were some erratic results, but later investigation makes it quite certain they were due to imperfect heating.

After the elastic measurements on the prisms were completed the extensometer was removed and the specimen loaded to failure. The ultimate crushing strengths which were thus obtained are given.

Table V. gives the same data for limestone prisms. The moduli for the unheated specimens are about the same as those obtained by the writer on a series of similar tests recorded in *Engineering News* of June 1, 1905, the average value of E obtained there being approximately 3,600,000 for a sand-lime-stone concrete 55 to 58 days old, and the average here found being 3,300,000 for prisms 20 days younger of like composition.

The value of E falls rapidly with increase of heat applied, the same as for the trap-rock mixture.

The surfaces of the prisms of both mixtures were covered with minute cracks after being subjected to over 750° and then cooled. These cracks increased in number and size as the heat became higher, and at 1,500° the prisms began to warp and disintegrate on cooling. This deterioration increased with time, and at the end of nine days one prism of each mixture was so badly crumbled it was unfit for test. The others were very much weakened. This disintegrating effect is probably due to the swelling of the cement as a result of recalcination.

The curves of all the heated specimens show a large deformation in the early part of the test when the loads were comparatively light. This gradually lessens as the loads increase and the middle portion of each curve approaches a straight line and then falls off again when ultimate failure begins. The large deformation at first is doubtless due to the closing up of the numerous fire cracks previously mentioned.

TABLE V.—COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY OF LIMESTONE CONCRETE PRISMS.

Specimen No.	Age in Days. Before Heating	Age in Days. Between Heating and Testing.	Heated to Degrees F.	Ultimate Strength in lbs. per sq. in.	E at 200 lbs per sq. in.	E at 600 lbs. per sq. in.	E at 1,000 lbs. per sq. in.	Condition after Heating.	Specimen No.
5....	30	....	...	1,427	3,000,000	1,715,000	1,028,000	....	5
6....	30	....	...	1,452	3,340,000	2,330,000	2,080,000	....	6
7....	30	....	...	1,246	2,500,000	1,715,000t	1,390,000	....	7
8A ..	44	4	500°	1,568	700,000	352,000	476,000	Specimen in good condition.......	8A
9A ..	44	4	500°	1,207	1,330,000	1,176,000	972,000	Same	9A
14B ..	45	7	750°	1,110	500,000	333,000	344,000	Not smooth on sides	14B
15B ..	45	7	750°	1,214	222,000	294,000	286,000	Good condition	15B
18C ..	51	4	1,000°	932	157,000	200,000	......	Stone on edge slightly calcined	18C
19C ..	51	4	1,000°	1,145	172,000	285,000	......	Same	19C
22D ..	57	3	1,250°	840	92,500	13,650	......	Stone entirely calcined to depth of 2-in.	22D
23D ..	57	3	1,250°	740	59,000	10,000	......	Same	23D
24E ..	57	19	1,500°	...	......	......		Stone entirely calcined, sides warped and shattered ..	24E
25E ..	57	19	1,500°	810	83,300	133,000	......	Same as 24E to lesser degree	25E

A peculiar characteristic of many set curves for both mixtures is the tendency they have to reverse direction and go back towards the axis. A conspicuous example appears in Fig. 4. No satisfactory explanation for this behavior has been suggested.

It will be noted that the elasticity of the specimens decreased rapidly with the increase of heat. This is clearly shown in Figs. 3 and 4, where all three curves for each test of *three typical speci-*

mens of each mixture are plotted to the same scale, showing the character of the total deformation, set and elastic curves without heating, and the corresponding curves for specimens which had been heated to 1,000° and 1,500° F. respectively.

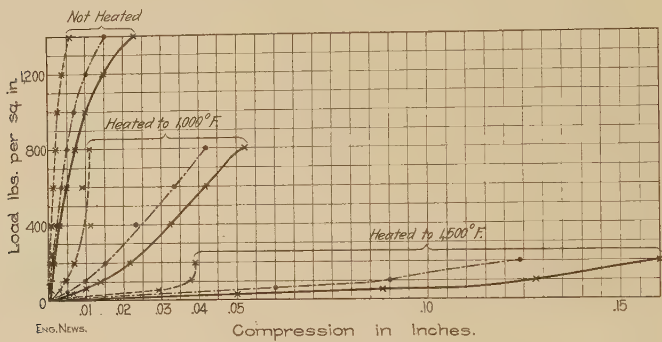


FIG. 3.—Typical Curves of Trap Concrete.

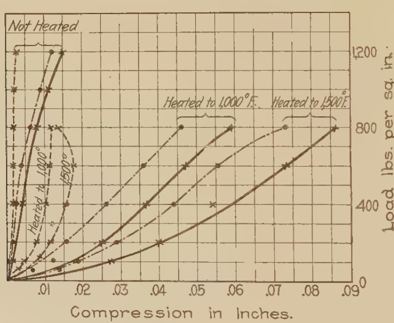


FIG. 4.—Typical Curves of Limestone Concrete.

FIGS. 3 AND 4.—Typical Stress-strain Curves of Normal Concrete and Concrete Previously Exposed to Temperatures of 1,000 and 1,500° F.

Test pieces 6 x 6 ins. 14 ins. high, of 1 : 2 : 4 concrete. Compressions measured on 12-in. length. Test pieces heated at ages of 33 to 57 days, then cooled slowly, and tested 3 to 19 days later.

Full lines give total deformation.

Dotted lines give sets.

Dot-and-dash lines give true elastic deformation = total deformation minus set.

The "true elastic" curves of *all* the prisms tested are grouped in Figs. 5 and 6, which indicate very plainly the gradual decrease of elasticity due to heating of the concrete.

The gradual decrease in strength of both cubes and prisms due to heat treatment is shown by the curves in Fig. 7. In general, the

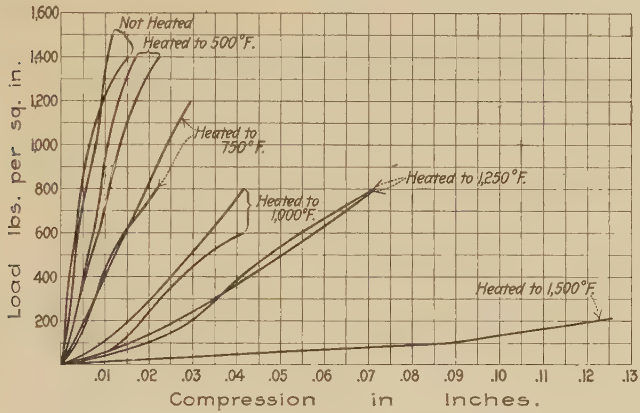


FIG. 5.—Elastic Curves of All Prisms of Trap Concrete.

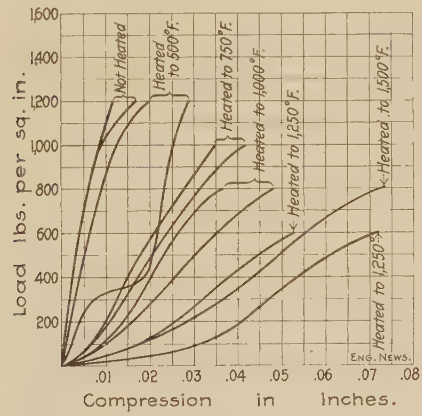


FIG. 6.—Elastic Curves of All Prisms of Limestone Concrete.

FIGS. 5 AND 6.—Elastic Curves of Normal Concrete and Concrete Previously Exposed to Various Temperatures from 500° to 1,500°F.

Test pieces 6 x 6 ins., 14 ins. high, of 1 : 2 : 4 concrete. Compressions measured on 12-in. length. Test pieces heated at ages of 33 to 57 days, then cooled slowly, and tested 3 to 19 days later.

Two specimens tested for each temperature.

All curves give true elastic deformation = total deformation minus set.

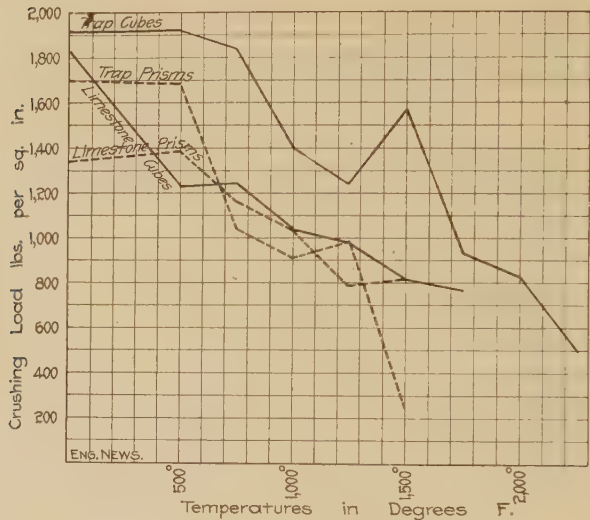


FIG. 7.—Curve of Crushing Strength.

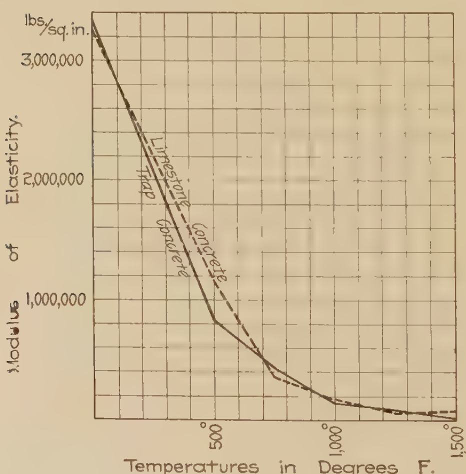


FIG. 8.—Curve of Modulus of Elasticity.

FIGS. 7 AND 8.—Variation of Crushing Strength and Elasticity of Concrete With Temperature of Previous Heat Exposure.

Test pieces 4-in. cubes, 6 x 6 ins. x 14-in. prisms; all of 1 : 2 : 4 : concrete.

Curves of elasticity give the modulus at unit stress of 200 lbs. per sq. in.

trap-rock mixtures were the stronger. There were some irregularities, which undoubtedly resulted from defective heating. Fig. 8 shows graphically the drop in the value of E for both mixtures due to heating.

As stated in the early part of this paper, the length of time a specimen should remain in the furnace to bring it to a certain heat was fixed beforehand, and with the 4-inch cubes the rate of heating employed appeared to give them uniform treatment throughout.

It was supposed the prisms would heat uniformly also in the time allowed, but subsequent results raised doubts regarding this. However, owing to the delays previously mentioned it was now too late in the season to duplicate the specimens and get them tested this spring, so the tests were completed and this report is rendered upon the data obtained.

Table VI. gives the actual times of heating for each class of specimen. It is known now that the time allowed for the prisms was not nearly sufficient to insure uniform temperature throughout. This is particularly true for the low temperatures. With the high temperatures the variation was probably not so great.

A test was recently made of the conductivity of the concrete in the prisms under the conditions of heating employed in the tests,

TABLE VI.—PERIOD OF HEATING THE TEST SPECIMENS.

Specimen.	Heated to Degrees F.	Time.
4-in. cubes	500°	55 minutes.
"	750°	1 hr., 35 min.
"	1,000°	2 " 15 "
"	1,250°	2 " 55 "
"	1,500°	2 " 55 "
"	1,750°	3 " 35 "
"	2,000°	3 " 55 "
"	2,250°	4 " 35 "
Prisms	500°	55 minutes.
"	750°	1 hr., 25 min.
"	1,000°	1 " 55 "
"	1,250°	2 " 25 "
"	1,500°	2 " 55 "

and it was found that by allowing 1 hour 15 minutes to bring the furnace temperature up to 750° F., and then holding that temperature constant, it required 2 hours 40 minutes more for the interior of two different prisms to attain the same temperature. Then raising the furnace temperature to 1,000° in 30 minutes, it required 1 hour 10 minutes more for the prisms to become uniformly heated throughout. The tests were made by imbedding thermo-couples

in the middle of the prisms, and connecting them by switch to the same galvanometer on which the couple in the furnace was recording. The concrete on which this test was made was 28 days old. In this instance it required 5 hours 35 minutes to obtain a temperature of 1,000° F. through 3 inches of concrete where the specimen was surrounded by heat on all sides, with no radiation possible.

This last experiment proved that the concrete had a very low conductivity and made certain the fact that the prisms tested had not been heated throughout to the temperature with which they are credited. At the same time, the writer believes, it explains the apparent discrepancy which exists between the results of these tests and some very satisfactory fire tests which have been made upon full-sized floor constructions. In a test of the latter character the fire is applied to one side only, and, although a heat of 1,700° to 2,000° is maintained for four hours, the concrete is such a poor conductor of heat that only a small portion of it ever reaches a temperature which would cause it to deteriorate to any great extent.

The writer is fully aware that the data presented are very incomplete and by no means sufficient upon which to base conclusions. The problem is an extremely difficult one, and at the same time very important. He plans to continue the investigation as opportunity offers and hopes that other investigators will give it their attention, so that in the near future some really reliable data may be obtained.

The investigation of this subject, together with the experiments detailed in this paper, was undertaken at the request of the Joint Committees on Concrete and Reinforced Concrete of this Society, and forms part of the broad inquiry into the properties of that material which is being conducted in the various testing laboratories and technical schools of the country, under the general supervision of that Committee.

The actual work of the investigation, together with the calculations and plotting of the curves, was done under direction of the writer by Messrs. F. H. Burch, Jr., and W. H. Connell, Jr., two students in the Department of Mechanical Engineering at Columbia University, and formed the subject of a research thesis problem in their senior year. Much credit is due these men for their faithful devotion to the work, and their energy in performing the tedious details. The presentation of this paper at this time was made possible only by their conscientious assistance.

DISCUSSION.

Mr. R. W. Lesley.—This paper seems to involve two important questions: one, the chemical character of cement, and the other going to the strength of beams and floor construction exposed to fire. The general proposition is one which should bring a good many engineers to their feet. **Mr. Lesley**

Mr. William Kent —There is one practical question I should like to ask. Suppose a warehouse is built of concrete, with a factor of safety of four, and there should be a fire in the combustible material stored in the warehouse—suppose, now there is reason to suspect that while the building did not fail, and the fire was put out, still it lasted such a long time that the concrete might have been heated to 1,500° F., and that the factor of safety of the building is possibly reduced to below two. Should the building be condemned and rebuilt, so far as the floor and the parts sustaining the pressure of the load are concerned? **Mr. Kent.**

Mr. Lesley.—The Chair will answer that from a practical experience. In Belgium there was a fire in a large knitting mill constructed under the Hennebique System entirely of concrete. Under the contract it was provided that certain tests of the floors and building should be had before acceptance. All the requirements were met and the owners took possession. Subsequently, there was a fire in the mill, the machinery was badly injured, some of the shafting twisted and a great deal of combustible matter was destroyed. The mill itself, however, was not injured in any way. Before starting up again, the owners, who held a guarantee from the Hennebique Company, wanted to assure themselves that the mill walls, floors, etc., still met the requirements of the original specifications, and that the Building Laws of Belgium had been complied with. Of course, the mill was a little bit older than when it was first constructed, and at the inspection after the fire it was ascertained that there was a gain of 20 per cent. in strength in every one of the required tests. Possibly that answers the question. **Mr. Lesley.**

Mr. Richard L. Humphrey.—I think the tests that Prof. **Mr. Humphrey**

Mr. Humphrey. Woolson has just described to us are extremely interesting and valuable and open up important fields in the investigation of properties of cement. It has given rise to a number of thoughts which I should like to offer by the way of comment. I understood the tests were made on cubes about sixty days old.

Mr. Woolson. MR. IRA H. WOOLSON.—Thirty to forty days.

Mr. Humphrey. MR. HUMPHREY.—In studying the effect of heat on hardened mortar or concrete, it is necessary to understand the process of hardening. From the moment the clinker is reduced to an impalpable powder, until it is finally hydrated, it is constantly undergoing changes produced by the reactions which tend to convert it from an unstable to a stable compound. It is doubtful whether these changes ever cease. The process of hardening in a cement is one of hydration resulting from the water which is added to it or which is absorbed from the air. The process of hardening in a mortar or a concrete is due to the crystallization or hydration of the cement which, during the mixing has been forced into the pores in the surfaces of the sand, gravel, stone, etc., in a plastic condition. This is the bond which holds the sand, stone or gravel together, and is destroyed at a temperature sufficiently high to drive off the water of crystallization.

The effect of heat, therefore, is one of degree, depending on the age of the concrete or mortar and on the intensity and duration of the heat. If the heat conditions are right the mass will be eventually reduced to its original state, prior to hardening. The larger the mass the more slowly is this water driven off, as it requires time for the water from the interior to reach the surface.

In addition to this water of hydration, there is also present in the void spaces of the mortar or concrete a certain amount of entrained or hygroscopic water, which, under the action of heat, expands, with a force sufficient to disrupt the mass—especially if very green. The amount of water will depend on the porosity, and decreases, therefore, as the density increases.

Green concrete when subjected to the action of heat, undergoes a sweating process in which this entrained water is gradually brought to the surface, this phenomenon disappearing with the absorption of the water either by the air or by the concrete in hardening. The expansion of this water under heat, which draws it to the surface, frequently disrupts the mass.

Professor Woolson's tests were made on six-inch cubes of green concrete. The superficial area of a six-inch cube bears a large ratio to the mass. The action of fire on such a test piece would be much greater than would be the case with a larger mass, such as the floors and walls of a building where the action would be largely on one surface only, and while this surface might be damaged by fire, it would not extend sufficiently into the mass as to seriously affect the strength. It would seem, therefore, that, while Professor Woolson's experiments show us what occurs in the case of small cubes of green concrete submitted to an intense heat, such information to be of practical value should be carried on with large masses of concrete which have hardened for six or more months. I believe in that event we would find nothing like the destructive action found by Professor Woolson. These fire tests are usually much more severe than likely to occur, because it is doubtful whether such conditions would ever be obtained in an actual conflagration. If the fire were sufficient to develop a red heat in the concrete, it is more than likely that the surrounding temperature would be such that it would be impossible to get near enough to turn on a stream of water, as the water would be volatilized before it could reach the surface of the concrete. **Mr. Humphrey.**

Whether a building should be torn down after a severe fire, as suggested by Mr. Kent, is dependent on the damage which has been done, which can be determined by suitable inspection just as in the case of any other building There are many examples of buildings of concrete which have successfully passed through severe fires.

A notable instance is the plant of the Pacific Borax Company at Bayonne, New Jersey. This plant consisted of a four-story building of reinforced concrete with wooden roof, door and window frames, as well as wooden posts for supporting two tanks of large capacity on the roof. Adjacent was a single-story building with reinforced concrete walls, covered partly by a wooden and partly by a corrugated iron roof, the latter being supported by a skeleton of steel. On each floor there was inflammable material which was practically consumed, as was all the wood work, including the twelve-inch wooden posts supporting the tanks on the roof. The steel skeleton completely collapsed, the columns folding up like a

Mr. Humphrey. ribbon. After the fire the building was cleaned, and the concrete appeared to be in good condition, showing no evidences of damage.

The character and age of the concrete has much to do with its fire-resisting qualities; the more dense and the older the mass the less water will be absorbed and entrained. Therefore a thoroughly hardened dense mass of mortar or concrete is likely to suffer little if any damage from the effects of fire.

It is to be hoped that Professor Woolson will continue his investigations on larger masses of older concrete.

Mr. Sabin. MR. L. C. SABIN.—One of the most important points brought out in this very instructive paper is the fact that it required nearly six hours for a temperature of 1,000° F. to penetrate three inches of concrete. It is probable that the concrete used in these tests was of a better grade than is usually employed, and thus while stronger, it was also less porous, and, therefore, its conductivity was greater than the concrete ordinarily used in building construction.

The fact that the modulus of elasticity decreases more rapidly as the result of the application of heat than does the compressive strength is also an interesting one, for it means that a larger share of the load on a beam is transferred to the reinforcement relieving the concrete when the latter becomes weakened.

During this meeting I have been told, by someone whose name I do not now recall, of some experiments in which briquettes were heated and some broken while others were replaced in water and regained a portion of their lost strength. I am sure it would be interesting if my informant would say something about these experiments.

Mr. Lazell. MR. E. W. LAZELL.—In our laboratory briquettes of standard size made from three different brands of cement were exposed to a temperature of between 1,000° and 1,200° F., in such a manner that the flame did not come in actual contact with the briquettes. The briquettes were held at this temperature for a period of six to eight hours and then allowed to cool down slowly.

A part of each lot of briquettes were broken when they were cold, and these gave practically no strength. The remaining briquettes of each lot were then immersed in water and were broken after having been in water 7 and 28 days respectively.

Mr. Lazell.

The tensile strength results obtained from the 28-day tests were practically the same as those obtained from similar briquettes which had not been subjected to heat. This pointed to the conclusion that cement which has been de-hydrated at the temperature of the experiment with a loss of strength, regains its strength on being immersed in water 28 days, thus indicating re-hydration of the cement.

Mr. Thompson.

MR. SANFORD E. THOMPSON.—The size of the specimen largely affects the result. We all know that the surface of the concrete is disintegrated by fire to depths, varying with the conditions, from ½ to 1½ in. If the surfaces of a 4-in. cube are disintegrated to the depth of ½ in. and this surface concrete rendered practically of no strength, the area of compression is reduced from 16 sq. in. to 9 sq. in., that is, nearly one-half, and the strength may be expected to decrease in the same ratio. If we assume the concrete to be affected to the depth of 1 in., its area of horizontal section is reduced from 16 sq. in. to 4 sq. in., or to one-fourth the original area. At a temperature of 1,500° F., a disintegration of at least ½ in. would be expected, and this of itself would explain the 50 per cent. reduction in strength shown in the diagram.

One of the most important subjects in fire resistance of concrete, and one which has never been satisfactorily investigated, is the comparative value of different rocks for the coarse aggregate. The question has often been raised whether a limestone mixture would not be changed to lime and the strength of the concrete utterly destroyed. While in these experiments the limestone mixture did not carry as high a load as the trap-rock concrete, it certainly did stand, when the reduction of area is considered, a very high stress throughout the test.

Mr. Hemstreet.

MR. G. P. HEMSTREET.—I should like to ask a question about the limestone and also make a little suggestion. Hudson River limestone is found on both sides of the river. That from the west side, which is now marketed in the greatest quantity in New York City, contains comparatively little carbonate of lime, and it is a very hard blue stone. That on the east bank contains a very large percentage of carbonate of lime and is a soft white stone. I should like to ask if it is known which limestone was used.

Mr. Woolson.

MR. WOOLSON.—Tompkins stone.

Mr. Hemstreet.

MR. HEMSTREET.—That contains very little carbonate of

Mr. Hemstreet. lime, and is a very hard blue stone. Another thing I should like to suggest would be the effect of moderate heat applied for a long length of lime. I happen to know of several concrete chimneys lined with fire brick for a portion of their height. If they should be subjected to a temperature of 600 to 800° F. for several hours a day and for several years, is that concrete going to gradually become weakened by the effect of the moderate heat for a long length of time? I think if we could have some concrete cubes put in a chimney and kept there for a year, it might be an interesting experiment.

Mr. Cummings. MR. ROBERT A. CUMMINGS.—In connection with the fire resistance of concrete I should like to record a little experiment I made last year in Pittsburg. A gentleman interested in the utilization of the waste products of blast furnaces brought me two sample bricks, one composed of Portland cement and sand from slag granulate, and the other of Portland cement and ordinary river sand, both mixed in the proportion of one to three. He wanted my opinion of their relative values for a building.

There was but slight difference in appearance and strength. But I placed them in the hot coal furnace of the boilers in the basement of our office building. In fifteen minutes the brick composed of river sand and cement had become disintegrated and partly fused. I was unable to take it out of the furnace except in the shape of a clinker. At the same time the slag sand brick had not yet gotten beyond an ordinary red heat and it took about half-an-hour to reach a white heat. While at a white heat I took it out of the furnace and placed it in a pail of ice water. The effect was surprising as only the edges of the brick crumbled.

I think it is an interesting experiment and indicates that the waste product of the blast furnace in the shape of slag is a good material for fireproofing. I do not know the exact age of the bricks, but it was probably six months.

Mr. Lesley. MR. LESLEY.—There are well-known results that have occurred in large fires which are practical tests of fire-proofing material. There have also been scientific tests conducted under the most skilful methods in a large way to determine this same fact. We all remember that the whole world was thrown into a turmoil some years ago by some laboratory experiments as to the effect of salt water upon Portland cement. It was feared that all

Mr. Lesley.

the docks and piers and everything built of Portland cement would fall away and would be disintegrated. In point of fact, the experiments disintegrated, but the docks and piers stood.

The best illustration of this latter state of facts is shown in a series of papers read before the Engineering Congress, at St. Louis, by two Japanese engineers, who built some enormous harbor work, which took five or six years to finish. The docks are still standing. The writer drew an absolute distinction between the laboratory results of salt water experiments, and the actual results of work done in thousands and thousands of cubic yards of this material.

Now you have another illustration which goes to the effect of two different natural forces on concrete. One is the effect of frost, and the other is the effect of heat on small bodies of concrete. We all know that if you take a small, or even a large, body of concrete, the first thing that happens is that what we call a chemical action is set up, and these little needles—angular pieces—get together and do what we call setting. The moment that is under way along comes a powerful influence known as Jack Frost, who stops that operation and sets up another one, which takes the water which is necessary for this chemical action to go on, and turns it into little crystals, hardening the entire mass, thus suspending chemical development, which again begins when the mass thaws. Now, it may be that the surface of that concrete has been injured, but that does not in any way destroy it as a whole.

So, also, if you put concrete to the test of fire and drive out the water the surface may be injured, but the surface that is injured is so small in proportion to the amount of concrete actually used that it can always be discovered, and in fact no harm results. In a small cube there is a great deal of surface destruction proportionate to the mass, but in a large mass the destruction of the surface, either by frost or heat, is so light that it will not destroy the reliability of the mass.

Those are two points that seem to come to my mind on this question.

Therefore, if we take a mass of cement which is in the act of setting, for we are all aware that cement or concrete does not get its final set before very long periods, and that the water in the mass is producing the chemical action, it would be readily agreed that

Mr. Lesley. all the chemical action has not yet been completed at the expiration of so short a period as 30 days. Consequently, if small cubes of cement, in which the chemical action is not yet finished, are exposed in a fiery furnace at the end of so short a period as 30 days, it is a grave question whether, first of all, enough water is not driven off in the first few moments to deprive the mass, which is endeavoring to go on and complete its chemical action of setting, of the means so to do; or, in other words, if by driving off the water at so short a period and in such small bodies, the mass of concrete has not been deprived of its means of livelihood.

Those familiar with the testing of long time sets of briquettes can thoroughly appreciate how long it is before the actual final setting of the cement is completed. Sometimes a little white dry spot is found in the center of the briquette at the end of a year or eighteen months, and it may be three or four years before this little white mass extends over the whole surface of the briquette, showing that no more water is admitted into the interior, and that setting has finally been completed.

Mr. Patton. MR. ALFRED G. PATTON.—As a member of the National Fire Protection Association I am very much interested in this discussion.

We know that the resistance of steel is reduced very quickly as its temperature rises. In our laboratory at Chicago numerous tests were made as to the penetration of heat into the cement mass, and the effect of the heat on the reinforcement. We know that the floor load is carried by the reinforcement. The tensile strength or cohesive properties of the cement not being sufficient to carry any considerable floor load. The moment the temperature of the steel is raised to any extent, it reduces the resistance of the steel below the factor of safety and something is going to happen. We find that steel raised to a temperature of 1,400° F. only retains about 10 per cent. of its resistance. The question is, how are we going to protect that steel from the action of the flames; not how far is the concrete going to resist their action. There have been buildings constructed of cement that failed under the fire test. In Baltimore there was a bank building that failed very decidedly. There were other structures, however, that stood the test of the fire. In one case the whole building was gutted, and the floor arches, beams and columns stood with practically no deterioration. Now there was some reason for that, and in our Committee

work some have come to the conclusion that, perhaps, the reason was from some inherent quality of the cement in one case, which permitted the heat to attack the steel work, and in the other case protected the reinforcement to such an extent that the arches failed to yield. It seems to us that there is greater necessity for protecting the reinforcement than worrying about the concrete. Mr. Patton.

I am glad to learn from Professor Woolson's experiment that cement is such a good non-conductor. We made a series of tests in Chicago, taking some beams, I think about 8″ x 11¾″ section through which three steel rods were put, one 1 in. from the bottom, another 2 in. from the bottom, the third, 3 in. from the bottom. Through holes bored into the tops of the beams thermometers were inserted, which rested on the steel rods to note the rise in temperature of the rods. A temperature of about 2,000° F. was maintained under the beams for four hours. We found that the temperature of the steel where there was only 1 in. of concrete covering rose to the danger point, in a very short period. Where there were 2 in. of covering much better results were apparent. I am requested by Mr. Hexamer, President of the National Fire Protection Association, and by the Chairman of our Committee, to express to you our sincere sympathy in your investigations, and our earnest desire to co-operate in any way to ascertain the true possibility of cement as a factor in fire-proof construction.

Mr. Leonard C. Wason.—I just want to bring out one thought, epecially in answer to the query of Professor Kent. In the designing of most columns which I have had to make, after determining the cross-section necessary for the strength, I have added about 1 in. on a side. By observation of the various fire tests which I have had an opportunity to see, I found the damage caused by the heat did not extend more than an inch into the surface. Therefore even if a column should lose 1 in. of surface by a severe fire, it still has in its center sufficient strength to carry the load, and that surface can be repaired by plaster without detriment to the entire construction. The attack of the heat is usually less severe on the columns than on the horizontal surfaces on the under side of floors. Therefore, the columns are not as likely to be damaged as the floor they support. Mr. Wason.

Mr. Rudolph P. Miller.—The New York Building Code prescribes a test for floors, which is designed to bring out the fire- Mr. Miller.

Mr. Miller. proof qualities of the materials entering into the construction. In framing the law, the protection of the steel frame structure now in general use was the main object aimed at. Reinforced concrete was practically unknown at the time the present law went into force. However, in testing reinforced concrete constructions, the requirements are followed as closely as possible. The prescribed test is essentially as follows:

A test structure of masonry, about fourteen feet wide by twelve to twenty feet long, of which the construction to be tested forms the roof, is erected. The necessary chimneys, draught openings, firing door and grate are provided. In this structure a fire of an average temperature of 1,700° Fahrenheit, determined by pyrometer, is maintained for four hours. At the end of that time, water at a pressure of sixty pounds is applied to the underside of the construction for five minutes, through a one and one-eighth-inch nozzle; then the top is flooded, and the sixty-pound stream is again applied to the underside for five minutes. During this test the construction carries a load of one hundred and fifty pounds per square foot, for which it is designed. After the application of fire and water, the load is increased to six hundred pounds per square foot. The conditions of approval are that no fire or water shall have passed through the construction, the load shall have been safely sustained, and the permanent deflection after the removal of the final load shall not exceed two and one-half inches. This test on full-size constructions no doubt has many advantages over the laboratory test described in the paper, though compared with them it is perhaps a crude test.

Since September, 1896, more than fifty such tests have been made under the supervision of the New York Building authorities, the majority of which were on cinder concrete construction. The practically uniform results in these cases have established beyond doubt the thoroughly fireproof character of the cinder concrete construction.

The results on the stone concrete have not been so satisfactory. Out of fourteen tests eight were successful. The failures were due probably in most cases to the fact that the test was made too soon, before the concrete had set sufficiently. In all the tests on stone concrete, water was driven off in great quantities during

the first half-hour. When the concrete has not had a chance to dry out sufficiently the expulsion of the water and conversion into steam are likely to disrupt it. Even in the successful tests the concrete was flaked off on the surface exposed to the fire, for a depth of about one inch. It, therefore, becomes of great importance that a sufficient thickness of concrete shall be provided around the metal reinforcement. **Mr. Miller.**

Another matter that deserves some attention is the time that should be allowed for the setting of the concrete before the test is made. A maximum limit should be fixed dependent on the interval between construction of a building and its occupancy in ordinary cases. New York practice in this respect was formerly thirty days, but more recently a longer time has been given before testing.

MR. WOOLSON.—There are just one or two points brought out by Mr. Miller that I wish to speak about. With regard to water in the concrete: where the test was made in thirty days, we have repeatedly noted in large floor tests, that the water has come out to such an extent that on a floor of 15-ft. span we have had anywhere from $\frac{1}{2}$ to $\frac{3}{4}$ in. of water on top during the first two hours of the test. That water came up out of the concrete. Whether it was held there mechanically or was water of crystallization disassociated by the heat, I do not know, but it is quite evident that the concrete was too green. This accumulation of water was particularly marked where the concrete stood during the early spring months and was thoroughly wet. The older the concrete, the better results we get. The only question is, what the age limit should be at which we should test it. **Mr. Woolson.**

Now, a word with regard to Mr. Kent's query. I might say that we have made repeated tests upon full-size floor units that Mr. Miller has spoken of, where we applied the heat for four hours, varying from 1,700 to 2,000° F. After the buildings cooled we loaded them again to 600 lbs. per sq. ft., and they carried the load successfully. That would seem to show that there was more than 50 per cent. of strength left in the concrete. In my judgment, the resistance to heat comes from the non-conductivity of concrete .The upper part of the floors were injured to a very slight extent. We found that water on red-hot concrete would break off some of the surface. In some cases,

Mr. Woolson. where girders were used, it knocked the concrete from the bottom part of the girder, and exposed the metal. A subsequent examination of buildings after the ten minutes application of water which we employ in our tests, showed the concrete was much better where the water had been applied than where it had not.

In the tests for conductivity it took about four hours to penetrate to the middle of a 6-in. block; in other words, to go through 3 in. of concrete where there was no possible chance for radiation, and the heat was coming in on all sides.

With regard to the sand and cement mixture that has been spoken of. In our testing station we have a building 14 ft. long, by 9 ft. wide and 9 ft. high, which is used for testing partitions. The ceiling and end walls are permanent; the side walls are removable, and new partitions are put in. The ceiling and end walls are made of a 1:4 mixture of sand and cement, 4 in. thick. We have had eight or nine tests in that building, averaging 1,700°F. for half of the time, and gradually approaching that during the rest of the time. Those walls are still in excellent condition; good for an indefinite number of tests, as far as I can see. I shall have to move the building soon and must tear it down; I am regretting the job I have on my hands, it is in such good condition.

The question has been raised regarding laboratory tests not being comparable with large practical tests. I agree thoroughly on that point. The only idea of these tests was to ascertain, if possible, what the effect on the specimen of concrete would be as to its elasticity and its strength, provided we could give it a uniform heat all through. That is all these tests bring out. They do not affect, I think, the general problem of concrete as a mass construction.

BRITISH STANDARD SPECIFICATIONS FOR CEMENT.

With Introduction by Mr. R. W. Lesley.

I find I am down to say something upon the British Standard Specifications for Portland Cement, or rather that I am to give some introduction of this important subject.

In considering the history of the preparation of the British Specifications, and the preparation of the American Standard Specifications for Manipulation, Analysis and Qualifications, the first thought that jumps to the eye is, that "Money makes the mare go."

When it is considered that the first attempt at specifications for cement in the United States, or rather at methods of manipulations of tests for cement in this country, was brought about from the appointment of a committee of the American Society of Civil Engineers in 1885, which committee reported certain suggestions for testing, and that these suggestions remained in actual force for a period of nearly twelve years, it can be readily imagined that there were very little funds for the careful investigation of this important subject by any scientific society.

When again it is considered that early in 1897 the American Society of Civil Engineers appointed another committee to report on the proper manipulation of tests for cement, and that this committee presented to the Society a Progress Report only on June 21, 1903, it can again be appreciated how difficult it is for any body having charge of the consideration of methods of manipulation of tests or the making of specifications for structural material, to proceed without a specialized laboratory, and proper funds for the conduct of their work.

The chemistry of the subject in this country does not seem to have been so serious a matter, taking but a short period of time to arrive at some conclusions on this subject, though these conclusions were adopted only by the New York Section of the Society for Chemical Industry for the Analysis for Limestones, Raw Materials and Portland Cements. Thus this work was that of but a single section of the Society for Chemical Industry.

The American Society for Testing Materials was also slow in the work of preparing cement specification, at least as judged by English methods. The first attempts were made in 1901, but nothing definite resulted, and finally in October, 1902, a new committee of this society met, consisting of many of the original members, together with representatives of a number of other scientific societies, and this committee, in about two years of work, was able to report on June 14, 1904, Standard Specifications for Cement, which were adopted by a letter-ballot of the Society at large on November 14, 1904, or three years after the work was begun.

In the present year, these specifications with which you are all familiar: the Progress Report of the American Society of Civil Engineers; the report on Method of Analysis, of the New York Section of the Society for Chemical Industry, above referred to, and the final report of the Committee on Standard Specifications for Cement, of the American Society for Testing Materials, have at last been sent out by the last named Society in the shape of a very well gotten up pamphlet, edited by the Secretary under the direction of Committee C on Standard Specifications for Cement. Thus, in our country, without funds, with nothing but the voluntary work of men who have contributed in some cases valuable time, and in other cases both time and money, this important matter involving the use of 25,000,000 to 30,000,000 barrels of cement a year, has dragged on from year to year, through no fault of any of those associated with the preparation and making of specifications, but simply for the lack of laboratory facilities for the men working in this important field—places where proper investigations could be carried on and where, with proper funds, the great work which has been finally completed, could have been completed with pleasure, ease and credit to all those who have generously given of their time and labor.

It is a subject for congratulation that at our meeting last evening, Messrs. Holmes and Humphrey, in the discussion of the plan and scope of the proposed investigation of structural materials under the auspices of the U. S. Geological Survey, have opened up to us and all engineering societies, a new vista of work to be done under Government auspices, backed by Government funds and under skilful men. They have opened up a field, where in a proper laboratory, all these questions which are agitating all these stand-

ing committees on testing and manipulation of cement can be thoroughly investigated, so that these committees may at all times, in their original inquiries, get proper results without taxing either the time or the funds of the individual or the committees. This is within the scope of the Government, and no class of materials deserves more thorough and full investigation than that great body of structural materials which goes to the building of all that is permanent in our country, whether of road-beds, railroads, large buildings, or the homes that house our people.

In England, a country which we are rather prone to consider slow, whose methods are sometimes stated to be behind the times, and whose ways of accomplishing things are held up by some of us to ridicule, it may be interesting to know that the preparation of the British Standard Specifications for Portland Cement took a little over a year to conclude. The history shows that the Committee on Cement was appointed at a meeting of the Main Engineering Standards Committee on March 27, 1903. The first meeting was held June 12, 1903. Twelve meetings were held, and the specification was passed in its final form November 23, 1904, and approved by the Main Committee on December 8, 1904.

In considering the promptness of this work, and in view of the general work of the Engineering Standards Committee in England, it is to be noted that this great body has the support not only of the British Government, but of a number of the Governments of the English Colonies. It is to be noted also, that this support is not a sentimental support, but an actual money support which enables the various committees to do good work, and to put out promptly specifications and volumes of reports in the best and most approved form. These funds enable the various committees of the Engineering Standards Committee to have examinations made in the most approved manner in laboratories at the expense of the Committee, and the day of gratuitous work, gratuitous services and gratuitous journeys in the preparing of these specifications, is at last over in England. The conditions which have existed in our country in the preparation of specifications, where engineers in a labor of love, at their own expense, have gone into deep investigations for the benefit of the standardizing committees, do not exist in England.

Another interesting fact in connection with this British Specification is, that the Government is actually represented by a number of its officers on the Committee: the Chairman, Mr. Matthews, representing the Crown Agents for the Colonies; Mr. Colson, representing the Admiralty; Mr. Fitzmaurice, the London County Council, and Mr. Lyster, the Liverpool Docks.

In addition to this, another point is to be noted, and that is, that while engineers and experts are on the Committee, and the manufacturers of Portland cement are well represented, the large contracting firms in England—whose names are world-wide for good work—have also been associated in the preparation of the Standard Specifications. The sentimental feeling that interests agitate those who prepare specifications, a feeling which our own Society has recognized is a false one, did not prevent the British Engineering Standards Committee recognizing the producer and the user of cement, as well as the engineer who stands between producer and consumer. The professional, as well as the non-professional engineer is recognized in the appointment of the Committee, and this recognition by such bodies as the Engineering Standards Committee, and by such societies as our own, which in every case recognizes the large producer, as well as the consumer and engineer, is going to bring about a feeling that the man who is at the head of a large contracting business or a large manufacturing business, is by the mere force of the position he has carved out for himself, a business engineer and to be ranked with engineers, though he may not in all cases have the skilled college training and education which they have been more fortunate in obtaining.

Now, coming to the specification itself and comparing it with our own, it is to be noted, first, that it is shorter, more compact and embodies in four large pages of printed matter covering a series of articles numbered from 1 to 12, what in our specification 32 pages are taken to describe. The specifications embody in the one case, 12 articles; in the other, 25 articles, which latter in turn cover 76 more. This condition of specifications in our country is due to the embodiment in and under the Standard Specifications of the American Society for Testing Materials, of the Progress Report of the American Society of Civil Engineers and the Report of the New York Section of the Society for Chemical Industry.

When, however, the two specifications are again compared, it will be noted that the British specification covers in its 12 articles all that there is to be said upon both manipulation of tests and specifications for tests, but that it omits entirely all reference to chemical analysis, which is evidently not considered to belong to a standard specification for Portland cement.

In comparing the two specifications, therefore, it is necessary to consider both the reports on methods of manipulation, and standard specifications above referred to alone, omitting the methods of analysis.

Without going over the entire methods of manipulation required by the Progress Report of the American Society of Civil Engineers, nor dealing with those parts of the British specification which have to do with methods of manipulation alone, but getting down simply to the differences in specifications, which, after all, are those which are likely to interest engineers, consumers and manufacturers, it may be stated in a general way that on the first item of the definition of Portland cement, the British specification suggests both water and sulphate of lime as materials which may be added to retard the setting, and covers both in its specification, limiting the amount in either case to 2 per cent. In the American specification, it will be noted that any addition, subsequent to calcination, is limited to 3 per cent.

On Specific Gravity, both specifications practically agree at 3.10, but the English specification raises the amount to 3.15, where the cement is sent direct from the mill to the laboratory in tightly sealed packages.

On Fineness, there is a material difference in the screens used, and it may be stated that the American specification, which has 8 per cent. on a No. 100 (10,000 mesh) sieve, and 25 per cent. on a No. 200 (40,000 mesh) sieve, would require a finer grinding than the British which has 3 per cent. on a 5,776 mesh sieve, or 22½ per cent. on a sieve of 32,400 meshes.

In the matter of setting, the specifications are again at variance. Our specifications require that the cement shall develop initial set in not less than 30 minutes, but must develop hard set in not less than one hour nor more than ten hours. The English Specifications recommends three distinct grades of setting time, designated as "quick," "medium" and "slow." The first in not less than

10 minutes, nor more than 30 minutes; the second in not less than ½ hour, nor more than 2 hours, and the third in not less than 2 hours nor more than 5 hours; and yet while these grades of time of setting are recognized, and each of them will have a material bearing upon the tensile strain of cement, the British specification in the matter of tensile strength has but one series of limits, namely:

7 days,	Neat............400 lbs.	28 days, Neat.........500 lbs.	
"	3 sand, 1 cement..120 lbs.		225 lbs.

The American specification, on the other hand, while not recognizing different classes of cement, so far as the time of setting is concerned, does recognize different strengths in tension, and has what the British specification has not, a 24-hour test, which may possibly in some quarters be considered superfluous for Portland cement. The American requirements are:

7 days, Neat..............450 to 550 lbs.		28 days, Neat.550 to 650 lbs.	
"	3 sand, to 1 cement.150 to 200 lbs.	"	200 to 300 lbs.

and are all higher than those of the British specification, which is no doubt due to the fact that there is more rotary kiln cement manufactured in our country, than possibly anywhere in the world.

Interesting, however, is the difference in the matter of gain in strength at longer periods, a new requirement which has only come into cement testing since the introduction of the Rapid Transit specification in New York.

In our country, in view of the fact that the matter has not been thoroughly settled, we recognize broadly that no cement shall show retrogression. In the English specification, however, this question of the increase of strength between the 7-day and 28-day periods is graded according to the initial strength shown by the cement at the 7-day period, which seems to be a very fair method of determining increased strength between the periods stated. In their specification, a cement showing neat 400 to 450 lbs. at 7 days is to gain 25 per cent. in 28 days; 450 to 500 lbs., 20 per cent.; 500 to 550 lbs., 15 per cent., and all over 550 lbs. at 7 days an increase of 10 per cent. at 28 days. This can readily be seen, is a very fair view of the subject, as a cement that pulls 600 to 700 lbs. at 7 days will have to increase very many pounds in tension to acquire the strength to show 25 per cent. increase between

the 7-days and 28-days periods, while a 10 per cent. increase would be a much more reasonable figure.

The great and salient difference between the two specifications, is that governing the test for constancy of volume, or what are known technically, as accelerated tests. In our specification, we have adopted the hot and cold water tests prescribed under the German Normal Test, and which have been in use so successfully for so many years, and have supplemented them by a steam test after the cement is set for 24 hours, consisting in exposing the pat in an open vessel to steam rising from a body of water beneath. The British have adopted what is known as the Le Chattillier test, which is fully described in the accompanying specification, and which so far has not been generally adopted outside of France. This is the part of the specification which up to date has attracted most criticism, by reason of possible inexperienced operators not producing similar results, with similar cements under similar circumstances.

The chemical requirements of the cement differ in the two specifications as follows:

In the American specification 1.75 per cent. of anhydride sulphuric acid is permissible, while in the English specification the limit is run up to 2.5. In England 3 per cent. of magnesia is allowed, as against 4 per cent. in this country. Insoluble residue in England is limited to 1.5 per cent., for reasons that may not be necessary in this country.

Another interesting thing in the English specification is that there shall be no excess of lime; that is to say, the proportion of lime shall not be greater than is necessary to saturate the silica and alumina presented, or represented by the formula:

$$\frac{\text{Cao}}{\text{Sio}_2\,\text{Al}_2\text{O}_3} = 2.75$$

Of course this would be covered by the analysis of cement described in the methods of manipulation of tests of the American Society of Civil Engineers, and the Methods of Analysis of the American Chemical Society, which are part of the American specification.

It is interesting to note that while the Standard American Specification has so far stood fire very well, and even its makers

could only suggest unimportant typographical corrections at our present meeting, the English Standard Specifications has not been so fortunate. From several quarters there has been some little criticism on the accelerated test, accompanied by statements of different results on the same sample. There have also been some other unimportant criticisms on chemical composition. Whether the difference in mental attitude to the new specifiations in the two great English speaking countries is due to the respective national characteristics of their people, is still to be determined. To the speaker, both specifications betoken good, careful thought and work conscientiously done.

BRITISH STANDARD SPECIFICATIONS FOR PORTLAND CEMENT.*

ISSUED BY THE ENGINEERING STANDARDS COMMITTEE.

SUPPORTED BY

THE INSTITUTION OF CIVIL ENGINEERS.
THE INSTITUTION OF MECHANICAL ENGINEERS.
THE INSTITUTION OF NAVAL ARCHITECTS.
THE IRON AND STEEL INSTITUTE.
THE INSTITUTION OF ELECTRICAL ENGINEERS.

PREFACE.

The Committee on Cement was appointed at a meeting of the Main Committee on March 27, 1903.

The first meeting of the Committee was held on June 12th, 1903, at which meeting the Chairman and Mr. Bertram Blount kindly consented to draw up a draft specification for the consideration of the members.

The Committee has held, in all, twelve meetings, and has collected a large amount of information from engineers, manufacturers and consumers of cement, which information has been carefully collated and considered by the Committee during their deliberations.

The specification was passed in its final form by the Committee at a meeting held on November 23d, 1904.

This report was later approved by the Main Committee at their meeting on December 8th, 1904.

ENGINEERING STANDARDS COMMITTEE.

The following is the list of members of the Committee on Cement entrusted with the drawing up of the standard specification:

*Reprinted under the authority and with the permission of the Publication Committee of the Engineering Standards Committee.

Committee on Cement.

William Matthews, Esq., C. M. G., (*Chairman*), representing the Crown Agents for the Colonies; C. Colson, Esq., C. B., representing the Admiralty; Lewis Solomon, Esq., representing the Royal Institute of British Architects; Bertram Blount, Esq., representing the Institute of Chemistry; Maurice Fitzmaurice, Esq., C. M. G., representing the London County Council; Sir John Mowlem Burt (John Mowlem and Company); H. W. Anderson, Esq.; H. K. G. Bamber, Esq. (Associated Portland Cement Manufacturers, 1900, Ltd.); E. W. Brooks, Esq., (Association Portland Cement Maufacturers, 1900, Ltd.); B. P. Ellis, Esq., (John Aird and Company); O. L. Ellis, Esq. (Association Portland Cement Manufacturers, 1900, Ltd.); Francis Fox, Esq. (Sir Douglas Fox and Partners); Howard H. Humphreys, Esq. (Cement Users' Testing Association); A. Lyster, Esq. (Liverpool Docks); J. A. McDonald, Esq. (Engineer-in-Chief Midland Railway Company); Charles S. Meik, Esq.; V. de Michele, Esq.; E. E. Pearson, Esq. (S. Pearson and Son, Ltd.); W. H. Roberts, Esq. (W. Lee, Son and Company, Ltd.); W. W. Squire, Esq. (Bristol Docks); J. Warbrick, Esq. (Sir John Jackson, Ltd.); C. H. Watson, Esq. (I. C. Johnson and Company, Ltd.); M. F. G. Wilson, Esq. (Admiralty Harbour Works, Dover); G. W. Yourdi, Esq. (Birmingham Corporation Waterworks).

BRITISH STANDARD SPECIFICATIONS FOR PORTLAND CEMENT.

Quality and Preparation.

1. The cement is to be prepared by intimately mixing together calcareous and argillaceus materials, burning them at a clinkering temperature and grinding the resulting clinker. No addition of any material shall be made after burning, except when desired by the manufacturer, and if not prohibited in writing by the consumer, in which case calcium sulphate or water may be used. The cement, if watered, shall contain not more than 2 per cent. of water, whether that water has been added or has been naturally absorbed from the air. If calcium sulphate is used, not more than 2 per cent. calculated as anhydrous calcium sulphate of the weight of the cement shall be added.

Sampling and Preparation for Testing and Analysis.

2. As soon as the cement has been bulked either at the manufacturer's works, or on the works in connection with which it is to be used, at the consumer's option, samples for testing shall be taken from each parcel,* each sample shall consist of cement from at least twelve different positions in the same heap, so distributed as to ensure, as far as is practicable, a fair average sample of the whole parcel, all to be mixed together and the sample for testing to be taken therefrom.

Before gauging the tests, the sample so obtained shall be spread out for a depth of 3 inches for 24 hours, in a temperature of 58 to 64 degrees Fahrenheit.

In all cases where consignments are of 100 tons and upwards, samples selected as above from each consignment, either at the manufacturer's works or after delivery at the works where the cement is to be used, shall be sent for expert testing and for chemical analysis. In no case shall cement so tested and analysed be accepted, or used, unless previously certified in writing by the consumer to be of satisfactory quality. Payment for such tests and analyses shall be made by the consumer, the manufacturer supplying the cement required for the same, free of charge.

The tests and analyses hereinafter referred to shall in no case relate to a larger quantity of cement than 250 tons sampled at one time.

When consignments of less than 100 tons have to be supplied the manufacturer shall, if required, give a certificate for each delivery to the effect that such cement complies with the terms of this standard specification, with regard to quality, tests, and chemical analyses, no payment being made by the consumer for such certificate, nor for the making of such tests and analyses.

Sampling at Manufacturer's Works.

3. Should it be deemed more convenient by the consumer, that the samples for testing should be taken at the manufacturer's works before delivery, the latter shall, in that event, afford full facilities to the inspector, appointed by the consumer, to sample

* Should the consumer desire to stipulate for any special quantity, the size of the heap must be stated.

the cement as he may desire at the said works, and subsequently to identify each parcel as it may be despatched, with that sampled by him. No parcel shall be sent away, unless a written order has been previously received by the manufacturer from the consumer to the effect that the material in question has been approved.

Fineness and Sieves.

4. The cement shall be ground to comply with the following degrees of fineness, viz.:

The residue on a sieve 76x76 = 5,776 meshes per square inch shall not exceed 3 per cent.

The residue on a sieve 180x180 = 32,400 meshes per square inch shall not exceed 22½ per cent.

The sieves shall be prepared from standard wire, and the size of the wire for the 5,776 mesh shall be .0044 inch, and for the 32,400 mesh, .002 inch. The wire shall be woven (not twilled), the cloth being carefully mounted on the frames without distortion.

Specific Gravity.

5. The specific gravity of the cement shall be not less than 3.15 when sampled and hermetically sealed at the manufacturer's works, nor less than 3.10 if sampled after delivery to the consumer.

Chemical Composition.

6. The cement shall comply with the following conditions as to its chemical composition. There shall be no excess of lime, that is to say, the proportion of lime shall be not greater than is necessary to saturate the silica and alumina present.* The percentage of insoluble residue shall not exceed 1.5 per cent.; that of magnesia shall not exceed 3 per cent., and that of sulphuric anhydride shall not exceed 2.5 per cent.

*The proportion of lime to silica and alumina shall not be greater than the ratio represented by $\frac{CaO}{SiO_2 + Al_2O_3} = 2.75$.

Mode of Gauging.

7. The quantity of water used in gauging shall be appropriate to the quality of the cement, and shall be so proportioned that when the cement is gauged it shall form a smooth, easily worked paste, that will leave the trowel cleanly in a compact mass. Fresh water shall be used for gauging, the temperature thereof, and of the test room at the time the said operations are performed, shall be from 58 to 64 degrees Fahrenheit.

The cement gauged as above shall be filled, without mechanical ramming, into moulds of the form shown in Fig. 1, each mould

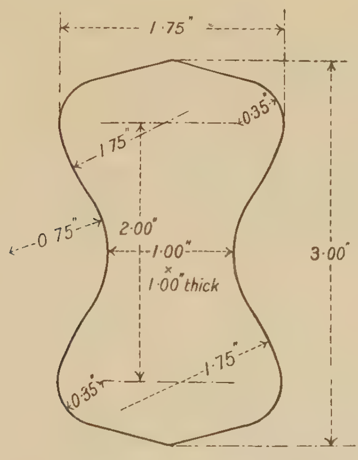


FIG. 1.—Dimensions of Briquette.

resting upon an iron plate until the cement has set. When the cement has set sufficiently to enable the mould to be removed without injury to the briquette, such removal is to be effected. The said briquette shall be kept in a damp atmosphere for 24 hours after gauging, when it shall be placed in fresh water and allowed to remain there until required for breaking, the water in which the test briquettes are submerged being renewed every seven days, and the temperature thereof maintained between 58 and 64 degrees Fahrenheit.

Neat Test.

8. Briquettes of neat cement of the shape shown in Fig. 1 shall be gauged for breaking at 7 and 28 days, respectively, six briquettes for each period. The average tensile strength of the six briquettes shall be taken as the accepted tensile strength for each period. For breaking, the briquette shall be held in strong metal jaws, of the shape shown in Fig. 2 the briquettes being slightly greased where gripped by the jaws. The load

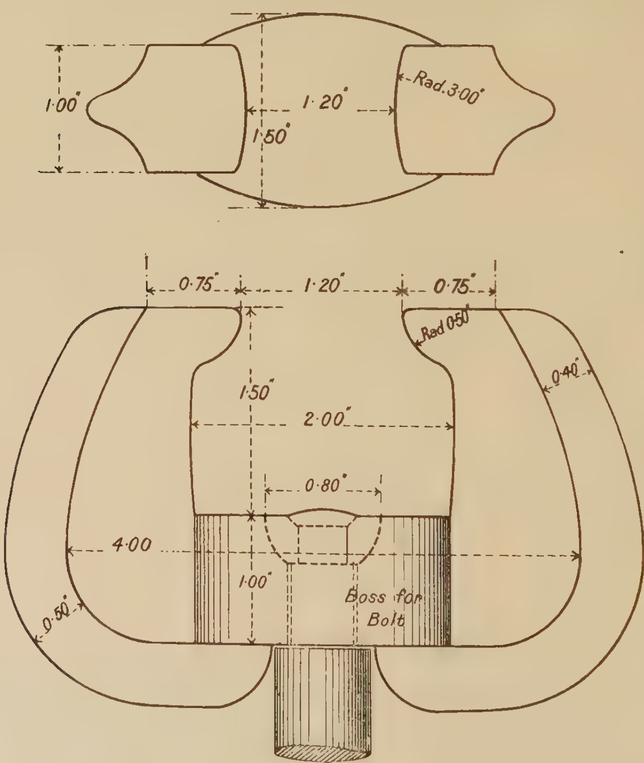


FIG. 2.—Details of Jaws for Holding Briquette.

must then be steadily and uniformly applied, starting from zero, increasing at the rate of 100 lbs. in 12 seconds. The briquettes shall bear on the average not less than the following tensile stresses before breaking:

7 days from gauging ......400 lbs. per sq. inch of section.
28 days from gauging ......500 lbs. per sq. inch of section.

The increase from 7 to 28 days shall not be less than:

25 per cent. when the 7 day test falls between 400 lbs. to 450 bls. per sq. in. of section.

20 per cent. when the 7 day test falls between 450 lbs. to 500 lbs. per sq. inch of section.

15 per cent. when the 7 day test falls between 500 lbs. to 550 lbs. per sq. inch of section.

10 per cent. when the 7 day test is 550 lbs. per sq. in. or upwards.

SAND TEST.

9. The cement shall also be tested by means of briquettes prepared from one part of cement to three parts by weight of dry standard sand, the said briquettes being of the shape described for the neat cement tests, the mode of gauging, the filling of the moulds, and the breaking of the briquettes shall also to be similar. The proportion of water used shall be such that the mixture is thoroughly wetted, and there shall be no superfluous water when the briquettes are formed. The cement and sand briquettes shall bear the following tensile stresses:

7 days from gauging ......120 lbs. per sq. inch of section.
28 days from gauging ......225 lbs per sq. inch of section.

The increase from 7 to 28 days shall not be less than 20 per cent.

The standard sand referred to above is to be obtained form Leighton Buzzard. It must be thoroughly washed, dried and passed through a sieve of 20x20 meshes per square inch, and must be retained on a sieve of 30x30 meshes per square inch, the wires of the sieve being .0164 inch and .0108 inch in diameter respectively.

SETTING TIME.

10. There shall be three distinct gradations of setting time, which shall be designated as "quick," "medium," and "slow."*

Quick.—The setting time shall be not less than ten minutes nor more than thirty minutes.

* When a specially slow setting cement is required the minimum time of setting shall be specified.

Medium.—The setting time shall be not less than half an hour nor more than two hours.

Slow.—The setting time shall be not less than two hours, nor more than five hours.

The temperature of the air in the test room at the time of gauging and of the water used shall be between 58 and 64 degrees Fahrenheit.

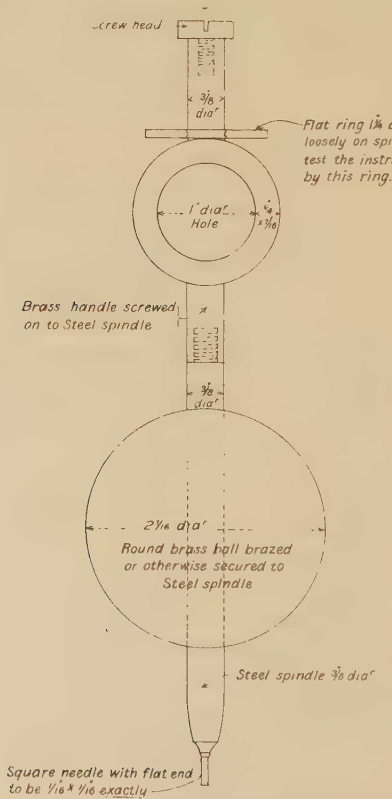


FIG. 3.—Sketch of "Needle" for Ascertaining Setting Time of Cement.

NOTE 1.—The total weight of the instrument, exclusive of the flat lifting ring, must be exactly 2½ lbs.

NOTE 2.—The end of the needle must be exactly $\frac{1}{16}$ inch square.

The cement shall be considered as "set" when a needle of the form shown in Fig. 3, having a flat end 1-16 inch square, weighing in all 2½ lbs., fails to make an impression when its point is applied gently to the surface.

SOUNDNESS.

11. The cement shall be tested by the Le Chatelier method, and shall in no case show a greater expansion than 12 millimetres after 24 hours aeration and 6 millimetres aften seven days aeration.

The apparatus for conducting the Le Chatelier test (Fig. 4) consists of a small split cylinder of spring brass or other

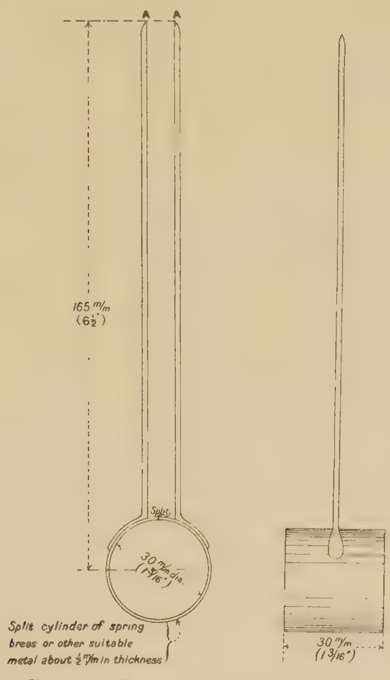


FIG. 4.—Le Chatelier Apparatus.

suitable metal of 0.5 millimetre (.0197 inch) in thickness, forming the mold, 30 millimetres (1 1/16 inches) internal diameter, and 30 millimetres high. On either side of the split are attached two indicators with pointed ends *A A*, the distance from these ends to the centre of the cylinder being 165 millimeters (6½ inches).

In conducting the test, the mould is to be placed upon a small piece of glass and filled with cement gauged in the usual way, care being taken to keep the edges of the mould gently together while this operation is being performed. The mould is then to be cov-

ered with another glass plate, a small weight is to be placed on this and the mould is then to be immediately placed in water at a temperature of 58 to 64 degrees Fahrenheit, and left there for 24 hours.

The distance separating the indicator points is to be then measured, and the mould placed in cold water, which is to be brought to boiling point in 15 to 30 minutes, and kept boiling for six hours. After cooling, the distance between the points is again to be measured, the difference between the two measurements represents the expansion of the cement, which must not exceed the limits laid down in this specification.

ACCEPTANCE.

12. No cement shall be approved or accepted unless it fully complies with the foregoing conditions.

IMPACT TESTS OF ASPHALT PAVING MIXTURES.

By Clifford Richardson and C. N. Forrest.

An impact test for determination of toughness of rocks has been designed by Mr. Logan Waller Page, of the Division of Tests, U. S. Department of Agriculture, and has been described by him in Bulletin No. 79, Bureau of Chemistry, as follows:

"This test is made on 25 mm. x 25 mm. (0.98 inch) rock cylinders with an impact machine especially designed for the purpose (fig. 8). Instead of a flat-end plunger resting on the test piece as in the cementation test, a plunger with the lower and bearing surface of spherical shape, having a radius of 1 cm. (0.4 inch) is used. It can be seen that the blow as delivered through a spherical-end plunger approximates as nearly as practicable the blows of traffic. Besides this, it has the further advantage of not requiring great exactness in getting the two bearing surfaces of the test piece parallel, as the entire load is applied at one point on the upper surface. The test piece is adjusted so that the center of its upper surface is tangent to the spherical end of the plunger, and the plunger is pressed firmly upon the test piece by two spiral springs which surround the plunger guide rods. The test piece is held to the base of the machine by a device which prevents its rebounding when a blow is struck by the hammer. The hammer weighs 2 kg. and is raised by a sprocket chain and released automatically by a concentric electro-magnet. The test consists of a 1 cm. fall of the hammer for the first blow, and an increased fall of 1 cm. for each succeeding blow until failure of the test piece occurs. The number of blows required to destroy the test is used to represent the toughness. A sufficient number of results have not yet been obtained with this test to warrant their publication."

It seemed to the writers that a test of this description might be very satisfactorily applied to determining the toughness of asphalt surface mixtures, substituting for the rock cylinder, one made by the compression of the hot asphalt surface mixtures uniformly in a suitable mold. Quite extensive experiments have been conducted on a number of asphalt surface mixtures, which have varied as regards the grading of the mineral aggregate and the character and consistency of the asphalt cement. The results which will be presented here are of considerable interest.

The test pieces were made as follows: The surface mixture was brought to such a temperature as would be found necessary in handling it upon the street, a weighed amount, such as has been found by experience would yield a cylinder after compression of 1 in. in height, is placed in a cylindrical mold, closely resembling the ordinary diamond mortar of the laboratory, of a diameter of $1\frac{1}{4}$ in. The mold is supported on a rigid block of timber $11\frac{3}{4}$ x $9\frac{1}{2}$ in. square by $32\frac{1}{2}$ in. high. The warm steel plunger is placed upon the top of the hot mixture above which is a cylinder of steel, weighing 10 lbs. running in grooved guides, which can be allowed to fall upon it from a height of 3 ft. After a few gentle taps to seat the plunger the weight is raised and allowed to fall freely ten times. The cylindrical mold is then inverted and the plunger introduced at the other end in a space left for this purpose by a boss on the base supporting the mold. Ten additional blows are then given on this end of the cylinder. In this way it has been found that a satisfactory and uniform compression is obtained. The cylinders are then weighted to determine if the density is satsfactory, and measured to see that they are of uniform height, 1 in. or near y so. On cooling they are ready to be tested, in the same manner employed by Mr. Page for rock cylinders, at whatever temperature may be selected.

Some of the results which have been obtained are represented in the accompanying tables and diagrams.

Before discussing the results it is well to consider what the work done upon the test piece amounts to, and what its destruction means. It had been suggested that the work required to produce fracture of the cylinder is the sum in kilogram metres of all the blows rather than that of the maximum blow, but it has been found that while, in the case of a Trinidad mixture, for instance, 29 blows are required when starting at a fall of 1 cm. and increasing 1 cm. at each subsequent blow, but two or three blows will produce the same result when applied immediately from a height of 29 cm. It is, therefore, a more accurate representation of the facts to express the results in the actual number of blows rather than by the sum of kilogram metres for work done by all the blows.

The work required to rupture such cylinders as have been tested, consisting of the same mineral aggregate and the same percentage of bitumen and of as nearly the same density as possible,

indicated very conclusively the relative binding power of the different asphalt cements which were examined and the relative toughness of the mixtures prepared with them, under the different conditions of temperature at which they were tested. Tables I, II and III give the data obtained for several well-known asphalts, while Tables IV and V express these results graphically.*

A number of tests have also been made upon cylinders prepared from old pavements which have been exposed to traffic for many years on the street. Some typical results are presented in Table IV. It is evident that the earlier asphalt paving mixtures were not as tough or satisfactory as those prepared to-day, and that this was largely due to a deficiency in bitumen although it possibly may be attributed in some respect to differences in the grading of the mineral aggregate. In order to determine whether this was the case surface mixtures in which there was considerable difference in the character of the sand of which they were composed have been tested, the results appearing in Table VI, and these results show that if filler is present in sufficient amount a mineral aggregate deficient in fine material may form quite as tough a surface mixture as one that is much finer. Of course, a surface mixture in which the mineral aggregate is coarse would be much more readily attacked by water.

The effect of water action on asphalt surface mixtures has also been studied, cylinders having been tested after exposure in water for 3 months in comparison with others of the same composition preserved in air. The results of these tests are given in Table VII, from which it appears that one bitumen may suffer more in this respect than another.

As a whole the results point to the probability that an impact test may prove of very considerable value in determining the merits of asphalt surfaces when used in connection with other reliable methods of examination.

*Acknowledgment is made to the *Engineering Record* for the cuts used in this paper.

TABLE I.—IMPACT TESTS OF ASPHALT SURFACE MIXTURES USING ASPHALT CEMENT OF 60 PENETRATION (BOWEN) 40 (DOW). TESTS MADE AT 40°F., 78°F. AND 100°F.

Analysis of the Asphalt Mixtures.

Asphalt used.	Test No.	Bitumen.	Pass. 200.	100.	80.	50.	40.	30.	20.	10.
Trinidad	75,833	11.3	15.7	10	9	29	11	7	5	2
Trinidad	75,834	11.4	15.6	10	11	25	13	8	4	2
Bermudez	75,620	11.5	15.5	12	10	25	13	7	4	2
Bermudez	75,621	11.5	16.5	12	8	27	12	6	5	2
Maracaibo	75,691	11.8	15.2	10	11	26	11	8	5	2
Maracaibo	75,692	11.5	15.5	11	9	27	12	6	5	3
Residual Pitch Texas	75,810	11.1	14.9	10	11	23	16	7	5	2
	75,811	11.0	16.0	10	9	26	12	9	5	2
Coal-tar Pitch	75,881	12.5	6.5	10	10	31	15	7	5	3

Tests Made at 40°F.

Asphalt Cement.	Test No.	Bitumen in Mixture.	Density of Mixture.	Number of Blows.	Height of Fall Max. Blow.
Trinidad Lake	75,833	11.3%	2.27	14	14 cm.
Bermudez	75,620	11.5%	2.22	11	11 cm.
Maracaibo	75,691	11.8%	2.15	14	14 cm.
Residual Pitch—Texas	75,810	11.1%	2.28	11	11 cm.

Tests Made at 78° F.

Trinidad Lake	75,833	11.3%	2.27	29	29 cm.
Bermudez	75,620	11.5%	2.23	17	17 cm.
Maracaibo	75,691	11.8%	2.17	12	12 cm.
Residual Pitch—Texas	75,810	11.1%	2.29	16	16 cm.

Tests Made at 100° F.

Trinidad Lake	75,833	11.3%	2.27	23	23 cm.
Bermudez	75,620	11.5%	2.24	16	16 cm.
Maracaibo	75,691	11.8%	2.21	10	10 cm.
Residual Pitch—Texas	75,810	11.1%	2.29	7	7 cm.

TABLE II.—IMPACT TESTS OF ASPHALT SURFACE MIXTURES USING ASPHALT CEMENT OF 80 PENETRATION (BOWEN) OR 60 PENETRATION (DOW).

Tests Made at 40° F.

Asphalt Cement.	Test No.	Bitumen in Mixture.	Density of Mixture.	Number of Blows	Height of Fall. Max. Blow.
Trinidad Lake	75,834	11.4%	2.25	16	16 cm.
Bermudez.............	74,621	11.5%	2.22	12	12 cm.
Maracaibo	75,692	11.5%	2.20	17	17 cm.
Residual Pitch, Texas ..	75,811	11.0%	2.28	16	16 cm.
Coal-tar Pitch	75,881	12.2%	2.25	8	8 cm.

Tests Made at 78° F.

Asphalt Cement.	Test No.	Bitumen in Mixture.	Density of Mixture.	Number of Blows	Height of Fall. Max. Blow.
Trinidad Lake	75,834	11.4%	2.26	29	29 cm.
Bermudez.............	75,621	11.5%	2.20	13	13 cm.
Maracaibo	75,692	11.5%	2.19	12	12 cm.
Residual Pitch, Texas ..	75,811	11.0%	2.27	14	14 cm.
Coal-tar Pitch	75,881	12.2%	2.23	15	15 cm.

Tests Made at 100° F.

Asphalt Cement.	Test No.	Bitumen in Mixture.	Density of Mixture.	Number of Blows	Height of Fall. Max. Blow.
Trinidad Lake	75,834	11.4%	2.25	20	20 cm.
Bermudez.............	75,621	11.5%	2.21	15	15 cm.
Maracaibo	75,692	11.5%	2.24	10	10 cm.
Residual Pitch, Texas ..	75,811	11.0%	2.29	7	7 cm.
Coal-tar Pitch	75,881	12.2%	2.22	18	18 cm.

TABLE III.—AVERAGE RESULTS OF IMPACT TESTS OF ASPHALT SURFACE MIXTURES FOR ALL TEMPERATURES, USING ASPHALT CEMENT OF 60 PENETRATION (BOWEN) OR 40 PENETRATION (DOW).

Asphalt Cement.	Bitumen in Mixture.	Density of Mixture.	Number of Blows.	Height of Fall Max. Blow.
Trinidad lake	11.3%	2.27	22	22 cm.
Bermudez	11.5%	2.23	15	15 cm.
Maracaibo	11.8%	2.18	12	12 cm.
Residual Pitch, Texas ..	11.1%	2.29	11	11 cm.

Average for All Temperatures Using Asphalt Cement of 80 Penetration (Bowen) or 60 Penetration (Dow).

Asphalt Cement.	Bitumen in Mixture.	Density of Mixture.	Number of Blows.	Height of Fall Max. Blow.
Trinidad	11.4%	2.25	21	22 cm.
Bermudez	11.5%	2.21	13	13 cm.
Maracaibo	11.5%	2.21	13	13 cm.
Residual Pitch, Texas ..	11.0%	2.28	12	12 cm.
Coal-tar Pitch	12.2%	2.22	14	14 cm.

TABLE IV.—GRAPHIC REPRESENTATION OF IMPACT TESTS OF ASPHALT SURFACE MIXTURES, USING ASPHALT CEMENT OF 60 PENETRATION (BOWEN), 40 (DOW). TESTS MADE AT 40° F., 78° F., AND 100° F.

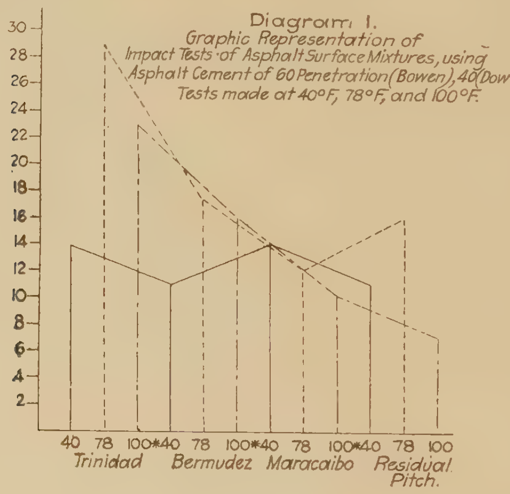


TABLE V.—GRAPHIC REPRESENTATION OF IMPACT TESTS OF ASPHALT SURFACE MIXTURES, USING ASPHALT CEMENT OF 80 PENETRATION (BOWEN), 60 (DOW). TESTS MADE AT 40° F., 78° F., AND 100° F.

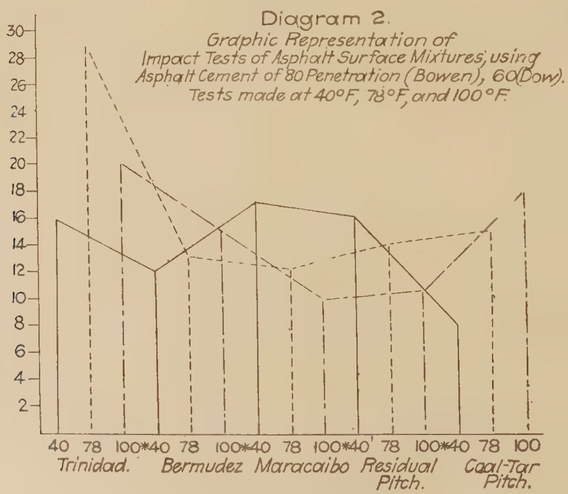


TABLE VI.—COMPARISON OF IMPACT TESTS OF OLD TIME ASPHALT SURFACE MIXTURES, THOSE OF 1904 OF VARIOUS GRADING, AND PRESENT STANDARD MIXTURE.

Analyses of the Mixtures.

Test number.	Year.	Bitumen.	Pass 200.	100.	80.	50.	40.	30.	20.	10.
70,354	N. Y. Stand. Mx. 1905	11.2%	17.8	12	10	27	12	5	3	2
30,035	1885	8.3%	13.7	15	10	20	13	9	6	5
30,828	1895	8.7%	11.3	10	12	34	17	4	2	1
30,831	1896	9.5%	12.5	11	13	31	15	5	2	1
73,285	1904	10.9%	11.1	16	17	33	6	2	1	3
73,394	1904	10.0%	11.0	5	4	16	16	15	11	12
73,374	1904	10.9%	14.1	7	7	28	16	10	5	2
73,456	1904	11.3%	13.7	8	8	30	14	8	4	3
.....	1904	12.0%	16.0	17	12	20	11	6	4	2

Impact Tests at 78° F.

Test number.	Mixture.	Bitumen in mixture.	Density of mixture.	Number of blow.	Height of fall max. blow.	Sand used.
70,354	N. Y. 1905 Standard	11.2%	2.25	20	29 cm.	....
30,035	1885	8.3%	2.23	6	6 cm.	....
30,828	1895	8.7%	2.24	7	7 cm.	....
30,831	1896	9.5%	2.23	15	15 cm.	....
73,285	1904	10.9%	2.25	28	28 cm.	Very fine
73,394	1904	10.0%	2.25	20	20 cm.	" coarse.
73,374	1904	10.9%	2.17	26	26 cm.	Deficient in fine.
73,456	1904	11.3%	2.16..	29	29 cm.	Do.
.....	1904	12.0%*	2.22	18	18 cm.	....

* High residual pitch bitumen.

TABLE VII.—IMPACT TESTS AT 78° F. OF ASPHALT SURFACE MIXTURES AFTER IMMERSION IN WATER FOR 3 MONTHS—USING ASPHALT CEMENT OF 65 PENETRATION (BOWEN) OR 45 PENETRATION (DOW).

Analyses of the Mixtures.

Asphalt.	Test number.	Bitumen.	Pass. 200.	100.	80.	50.	40.	20.	30.	10.
Trinidad..	.. 69,645	10.5	16.5	11	12	23	13	7	4	3
Bermudez	.. 70,354	11.2	17.8	12	10	27	12	5	3	2

No. of blows.

Asphalt Cement.	Test.	Bitumen in mix.	Density of mix.	Orig. mat.	After immersion.	Height of fall max. blow.	Lbs. per sq. yd. of water absorbed by cyl.
Trinidad lake .	69,645	10.5%	2.22	21	20	20 cm.	.129
Bermudez	70,354	11.2%	2.25	15	13	13 cm.	.157

THE COLLECTIVE PORTLAND CEMENT EXHIBIT AND MODEL TESTING LABORATORY OF THE ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS, AND THE RESULTS OF TESTS AT THE LOUISIANA PURCHASE EXPOSITION, ST. LOUIS, MO.*

By Richard L. Humphrey.

Great expositions mark the progress made in the industrial world, and emphasize the advance in particular lines. The Louisiana Purchase Exposition was no exception. Those who were fortunate in being able to attend the Exposition at Chicago in 1893 and St. Louis in 1904 doubtless observed the progress which had been made in the branches in which they were especially interested. To those interested in cement, a very noticeable feature of the former was the absence of an American Portland Cement Exhibit, and the elaborate German exhibits of this material. This was naturally to be expected at a period when American Portland cement was hardly known and was regarded as of doubtful quality, while German Portland cement was universally used and was held in very high regard. The total consumption of Portland cement in 1903 was 3,264,801 barrels, of which 82 per cent. was of foreign and only 18 per cent. of domestic manufacture. In the decade which has since elapsed a great change has taken place in the production and consumption of American Portland cement. The production has increased 450 per cent., while the importations have fallen off about 73 per cent.; the consumption now exceeds 26,505,881 barrels, and this country has grown from one of the smallest to one of the largest Portland cement producing countries of the world.

* Presented jointly to the Association of American Portland Cement Manufacturers and the American Society for Testing Materials.

It was quite appropriate that this remarkable growth of the cement industry in America should be fittingly exploited at St. Louis, and it was natural that this exploitation should be made by the American Portland cement manufacturers in a collective exhibit. Such an exhibit formed the gateway to the mining gulch of the Exposition and was one of the most attractive of the outside individual exhibits. The fact that there were no foreign cement exhibits worthy of note, served to emphasize the withdrawal of the foreign Portland cement from the American market, resulting

FIG. 1.—General View of Building.

from the development of the American Portland cement industry. In yet another particular was this collective exhibit noticeable. In 1893 the American Portland cement manufacturer, while not openly hostile to the inspection and testing of his product, was nevertheless not a strong advocate and frequently rebelled against the restrictions placed on him by the testing engineer. Yet it was because of this continual raising of requirements which compelled the manufacturer to improve his product, that he occupies a premier position in the cement industry to-day. We now find the manufacturer no longer the opponent but the firm advocate of

proper methods for testing. This new attitude was shown in the equipment and operation of the Model Testing Laboratory in which was exploited the methods for testing cement proposed by the special committee of the American Society of Civil Engineers, whose report was distributed gratuitously. Only those who had an active part in the erection of buildings and installation of exhibits at a great exposition can appreciate the vexatious delays occasioned by unforseen difficulties; this was particularly true of the cement exhibit.

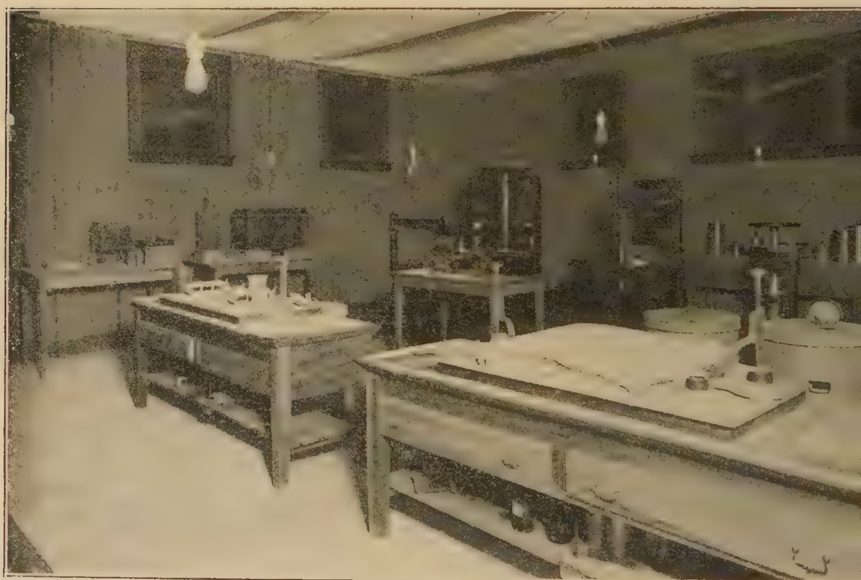


FIG. 2.—General View of Laboratory.

It was originally intended that the work of construction should be carried on during the Exposition as a working exhibit. To secure greater advantages in an educational way it was subsequently decided to complete it as soon as possible, but before this could be accomplished the Exposition was well towards its close. The buildings, and the installation of the equipment of the laboratory and of the other exhibits were quickly completed and the whole placed in a working condition.

The completed Exhibit formed a comprehensive exposition of the Portland Cement Industry, comprising:

1. A collection of the raw materials from which Portland cement is manufactured, together with samples of this material taken in various stages of manufacture, to the finished product.

2. A collection of the various sands, gravels, cinders, broken stone and metal used in concrete, together with photographs and models of structures built of concrete in all parts of the world.

3. A library of books and files of the various technical journals devoted to cement, mortar and concrete.

FIG. 3.—View of Cement Exhibit.

4. A completely equipped model testing laboratory.

5. A collection of machines for mixing and molding concrete; and,

6. A collection showing the many forms in which Portland cement is used.

The exhibit building, one of two permanent structures, which has been presented to and accepted by the Park Commission of the City of St. Louis, Mo., is an excellent example of reinforced

concrete construction, and consists of three pavilions separated by intermediate courts and connected across the front by a continuous loggia, the roof of which is covered with cement tiling (Spanish pattern) of a rich red color. This coloring, together with the red tinting of the ceiling of the loggia, relieve the general grey tone of the walls and forms an agreeable color contrast. The style, Spanish Mission, and the rough-finished walls are particularly well adapted to the use of concrete.

As much interest was manifested in the finish of the walls, a description of the method used is added. The forms were removed at the end of twenty-four hours after casting and the outside surface was then scrubbed with a soft wire brush, washing with a hose at the same time,—this removed the cement and sand from the surface, leaving the stone of the concrete prominently exposed and producing the effect of rough casting. The advantages of this method are, first the production of a uniform color, and second the prevention of the appearance of hair cracks by the removal of the excess of neat cement.

The superstructure of reinforced concrete rests on a substructure of concrete, carried to a solid foundation, reaching in some portions a depth of 16 feet. American Portland Cement, Mississippi River sand, chatts (the screened tailings from the Missouri lead mines) and broken stone were used in the concrete in proportions of one part cement, three parts sand, and six parts broken stone for the substructure, and one part cement, two parts sand, and four parts chatts for the superstructure.

The roofs, covering the pavilions, are of ferro-inclave construction, 3 in. thick; consisting of corrugated sheet iron plastered on both sides with a mixture of Portland cement and sand.

The walls are reinforced every foot, both horizontally and vertically, by $\frac{1}{4}$-in. round rods. The beams of 30-ft. span have $2\frac{5}{8}$-in. diameter round rods, in the upper and $2\frac{7}{8}$-in. rods in the lower portion. For the 20-ft. beams $\frac{1}{2}$-in. round rods are used in the upper and $\frac{3}{4}$-in. rods in the lower portion. The stirrups are $1\frac{1}{4}$-in. wide No. 16 gauge iron.

The interior walls were floated while green with a mortar of cement and sand, and subsequently tinted with rich water colors, the reception rooms being finished a deep vermilion, the laboratory a warm terra-cotta, while the exhibition room is finished in a

deep green. The ceilings are uniformly of a rich cream color. Between the windows, bordering the interior courts, are medallions of the labels of the various companies, cast in Portland cement.

The south end pavilion was used as a reception room and office, and contained a reference library of books and files of the leading technical journals devoted to cement, mortar and concrete. The north end pavilion served as an exhibit room, in which was displayed the collection of the characteristic raw materials from various parts of this country used in the manufacture of Portland cement, showing raw material in the various stages of preparation to the finished product. The coal used was also shown in the raw and finished state. In all three pavilions were transparencies of some of the Portland cement plants in this country.

The various forms of metal used in reinforceing concrete, the sand, gravel, cinders, and broken stone, from all over the country, were on exhibition. Besides, there was a collection of photographs of work built of concrete, from all over the world, and of tests made to establish the fire-resisting qualities of concrete.

The wonderful growth of the Portland Cement Industry, the steadily increasing consumption of American Portland cement, and the decreasing consumption of natural and imported Portland cement was shown graphically, while by means of maps a comparison was made between the plants in existence in 1890 and those in existence at the present time.

The central pavilion contained a thoroughly modern and admirably equipped testing laboratory, the finest that has ever been installed in this country. This laboratory was in daily operation, demonstrating the methods used for testing cement and concrete.

The mixing and molding were performed on two especially designed tables, each of which is 7 ft. long, 28 in. wide, and 3 ft. high at the main portion; each end (32 in. above the floor) has a one-inch plate-glass mixing slab 2 ft. square. In the central part of one of these tables a galvanized iron pan 2 ft. square and 6 in. deep was inserted provided with a cloth-covered wire screen top, and a wooden rack in the bottom ¾-in. high. The pan was filled with water to the top of the rack and the cloth was kept wet. The test pieces used in the determination of time of setting were

placed on this rack and kept there during the test, being removed from time to time to make trial tests of the setting. The object was to maintain the test piece under uniform conditions during the test.

The tension and compression test pieces, as well as those for the soundness, were kept in moist air for the first 24 hours after molding. For this purpose there was a moist closet, which consisted of a soapstone box 4 ft. wide, 18 in. deep and 2 ft. high resting on a wooden frame 30 in. high. The closet has a central vertical partition, and was provided with wooden doors covered with planished copper. The bottom was made water tight, and holds about 6 in. of water; the sides have cleats for holding four sets of glass shelves 4 in. wide, 22 in. long, on which were placed the molds containing the neat cement briquettes. At the bottom over the water is a wooden rack, on which were placed the molds containing the mortar briquettes.

The test pieces were removed at the end of 24 hours, marked, removed from the molds, and for all tests for longer periods than 24 hours they were immersed in tanks. These tanks were of soapstone, provided with running water and were arranged in tiers of three each. There were six tanks in all, each 6 ft. 7 in. long, 30 in. wide. One of the upper tanks is 30 in. deep, and was used for the storage of large beams and cubes of concrete; the remaining tanks were all 6 in. deep (inside measure). Each tank was provided with two inlet and two outlet pipes, by which the water was maintained at any constant level. An instantaneous gas water heater was connected to the supply so that the temperature of the water could be maintained practically at 70° F.

For the determination of time of setting and normal consistency there were two Vicat Needle apparatus, one made by Tinius Olsen and Company, and the other imported from Germany.

For the tension tests there was a long and short lever machine. The former, made and loaned by Tinius Olsen and Company, of Philadelphia, was driven by an electric motor, and was automatic in the application of the weighing load; while in the other, made and loaned by the Fairbanks Machine Company, of New York, the load was applied by a stream of shot flowing into a bucket suspended to one of the levers, the slip of the clip on the briquette being taken up by means of a worm which operates the

lower clip, a feature which has added very considerably to th value of this type of machine.

For the compression tests there was a 40,000-pound, hand-driven machine built and loaned by the Falkenan-Sinclair Machine Company, of Philadelphia, and a 200,000-pound electric motor-driven machine built and loaned by Tinius Olsen and Company, of Philadelphia. This machine was equipped with table for transverse tests up to 10 ft. clear span, and was provided with a ball and socket bed plate for compression tests up to 12 in. The former machine was new, having been built especially for this exhibit, at the writer's request.

The proper way for testing cement mortars or concretes is in compression, as it approaches more nearly the conditions of actual use. When we design structures in concrete, we disregard the tensile strength of the concrete, and figure entirely on the compressive strength, incorporating in the beam or column sufficient metal to take up the tensile stresses. Why then should we test cement in tension? We will find the reason in practical rather than theoretical conditions. The average laboratory, or more specifically, the usual laboratory of the consumer, is not provided with a large fund for its equipment or operation The usual machines used for tests of strength are the tensile testing machines, ranging in price from $90 to $200. The compression machines sell for from $800 up, besides requiring power for their operation. Their cost places these machines beyond the reach of all except the large permanent laboratories. The 40,000-pound machine, in the laboratory will sell for $300. It is to be hoped that under favorable cost conditions, compression tests will come into increasing favor, and in time supplant the unsatisfactory tension tests.

It is an encouraging fact, and worthy of note in passing, that tests of cement are being regarded of much greater importance and are receiving correspondingly greater attention than formerly. This is unquestionably the result of the increasing and varied application of cement for constructive purposes, and under conditions which render the quality of the cement of paramount importance.

The most important test that can be applied to cement is that for soundness or constancy of volume, as it is of the highest importance

that a cement once set shall remain volume-constant. No entirely satisfactory test has been devised for this purpose. In the apparatus used in this laboratory the pats were placed on a rack, over boiling water, the surface of which was kept constant by means of a constant level bottle. The pats were maintained in an atmosphere of steam at a normal pressure. No matter what the character of the water may be, the steam will be pure, and free from the objectionable qualities that may enter into the boiling test.

The laboratory was provided with the usual standard sieves: Nos. 100 and 200 for cement; Nos. 10, 20, 30, 40, 50, 60, 80, 100 and 200 for sands, and with an analytical balance and scales, with the necessary metric weights, made and loaned by Henry Troemner, of Philadelphia. For the specific gravity determinations the Le Chatelier's apparatus was used.

There was also a Bauschinger apparatus for measuring the expansion of cement, and the usual measuring devices for the various tests.

In the rear of the building were the outside exhibits which served to illustrate a few of the many uses to which Portland cement is put, and some of the methods employed in mixing and molding.

The limited time available after the completion of the exhibit was insufficient for the execution of any elaborate series of investigations. It became necessary, therefore, to concentrate the work on such tests as would be productive of data of the greatest value. The tests made were of two kinds: those made in the laboratory and those made among the outside exhibits, consisting for the most part of full size concrete beams and floor slabs which were loaded to destruction with pig iron. The work in the laboratory was confined to illustrating proper methods for testing cement and to investigations of the comparative value of the various sands, gravels, and broken stone used in some of the principal cities of this country.

Inasmuch as the exhibit was the joint work of some forty Portland cement companies it was deemed undesirable to advertise any particular company either by permitting individual exhibits or by the use of a particular brand. The building was built with cement which was a mixture of four brands of Portland cement,

readily found in the St. Louis market. The same policy was followed in the cement used in the laboratory tests; in which case a thorough mixture was made of five brands, which gave a standard Portland cement of sufficient quantity for the entire series of tests.

It is a rather curious fact, that the average of the tests of the mixture of the five brands was higher than the average of the tests of the individual brands. The result of these tests is summarized in Table I, Pl. VI. The variations

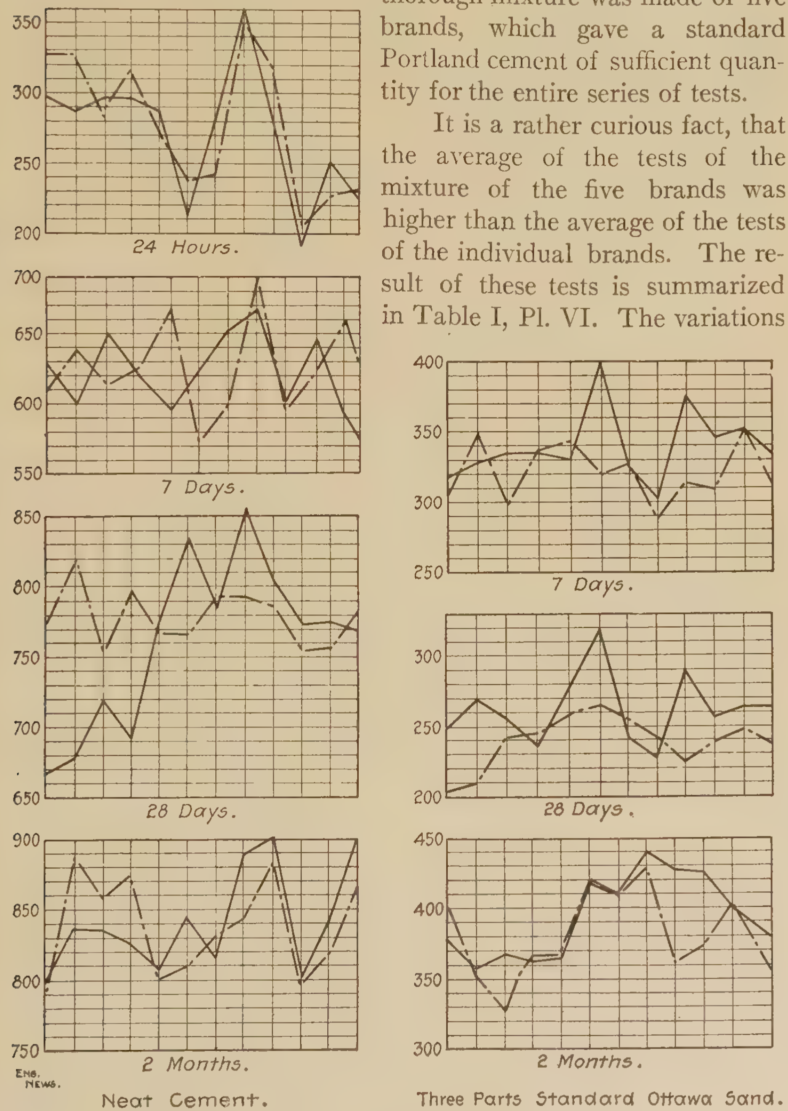


FIG. 4.—Diagrams of Results of Tests of Cements and Mortars, Showing Effect of "Personal Equation."

in the results of these tests are due to two causes: (1) Changes in the quality of the cement due to atmospheric conditions, and (2) changes occasioned by the variation in the "personal equation" of the operator. Two men made the same tests simultaneously, using similar apparatus and methods. The effect of the "personal equation" and other changes is set forth in the diagrams Fig. 4;* the ordinates being the successive tests as made, practically, at daily intervals. These men were inexperienced in the beginning and it will be noted in the diagram that while the results were far apart in the beginning they became more concordant as experience was acquired.

In the comparative tests with the standard cement of sands, gravel, and broken stone it was only possible in the limited time to test those from the following points: Berkshire, Mass.; Cleveland, Ohio; Cowe Bay, Long Island, N. Y.; Chicago, Ill.; Dallas, Tex.; Kaw River, Iola, Kan.; Philadelphia, Pa.; Plum Island, Boston, Mass.; St. Louis, Mo.

The results of these tests will be found in Tables III, IV, V, Pl. VII, and diagram Fig. 5, Pl. VIII. A study of the latter is quite interesting in that it shows the relation between the size of the particles and the percentage of voids. The tests seem to indicate that the smaller this percentage the greater is the strength of the mass; this percentage being dependent on the size of the particles. Where the particles are well graded from coarse to fine, the percentage of voids is reduced to a minimum. This was found to be true of the unscreened sands and gravels, the highest results being obtained with the sand or gravel containing the least percentage of voids and showing the best gradation in the size of particles from coarse to fine.

When this material is screened to one size as 20–30 the per cent. of voids and the strength become practically the same, regardless of the strength previously obtained with the unscreened material. In this particular it apparently matters not what the geological origin of the material is, provided it is not undergoing further decomposition. It is also observable that the specific gravity of the sands and gravels is practically the same.

An examination of Table IV will show the very small percentage

*Acknowledgment is made to the *Engineering News* for the cuts used in this paper.

SAMPLE NUMBER	FINENESS IN PER CENT RESIDUE IN SIEVE		TIME OF SETTING IN MINUTES		PER CENT WATER	TENSILE STRENGTH POUNDS PER SQUARE INCH														
						NEAT									SAND					
	NO.100	NO.200	INITIAL	HARD		1 DAY	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL	7 DAYS	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL	28 DAYS	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL	7 DAYS	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL	28 DAYS	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL
A	9.83-	26.99-	279-	510-	19½	112 121 117	116	125	532 647 550	548	536	670 684 783	712	706	155 180 170	168	158	232 260 255	249	262
A	9.15	25.90	286	436	19½	142 124 133	133		539 579 465	528		680 730 690	700		165 150 126	147		277 285 263	275	
B	8.80-	25.89-	58-	110-	20½	234 206 220	220	235	591 602 615	603	628	790 756 776	776	758	287 266 270	274	268	437 423 396	419	403
B	9.00	26.86	62	120	20½	228 272 250	250		641 650 669	658		743 721	729		259 283 244	262		387 395 380	387	
C	11.90	28.48	263-	435-	20.0	112- 107- 110	130	127	639 626 580	615	610	858 874 739	824	849	237 267 230	245	224	382 372 422	392	374
C	10.00	26.30	215	435	20.0	125 120 123	123		595 580 636	604		852 865 904	874		190 191 226	202		345 358 362	355	
D	899-	24.30	40-	171-	20¾	216 247 231	231	241	595 622 580	594	582	673 721 778	724	710	260 274 280	271	267	345 381 374	367	371
D	8.40	26.95	45	185	20¾	246 253 250	250		572 670 585	596		685 727 675	696		262 233 285	263		413 393 320	375	
E	4.69-	22.33	35-	265-	20½	195 196 196	196	211	542 545 597	561	558	690 670 631	664	663	220 211 208	213	202	317 335 343	332	313
E	4.10	21.50	39	280	20½	230 221 226	226		520 595 520	545		640 673 671	661		170 217 187	191		310 291 280	294	
AVERAGE	8.84	25.34	185	298	20¼		179	188	583	582		740	757		234	224		352	345	
AVERAGE	8.13	25.39	149	290	20¼		196		580			732			213			337		
STANDARD	7.79	24.85	130	314	20.0		274	277	621	622		761	770		263	251		391	380	
CEMENT	7.75	25.60	151	332	20.0		280		623			779			240			368		

TABLE I.—Showing Results of Tests of Five Brands of American Portland Cement and of Samples Made From a Mixture of All Fine Brands.

SAMPLE NUMBER	AGE	PROPORTION	WEIGHT PER CU. FT.	AREA	COMPRESSIVE STRENGTH IN LBS ULTIMATE	COMPRESSIVE STRENGTH IN LBS PER SQ. IN.	REMARKS
1	60 DAYS		139.98	35.25	58500	1659	SLIGHTLY SPALLED AT EDGES.
2		1 CEMENT	143.87	35.25	59910	1700	DO.
3		1 SAND	143.10	35.15	68500	1943	DO.
4		5 CHATTS	143.87	36.00	70350	1954	DO.
5			143.36	35.33	48000	1359	DO.
6			144.06	35.63	64250	1803	DO.
AVG			143.04	35.42	61585	1740	
7	DO.	1 CEMENT	143.18	35.84	29450	822	CORNERS SPALLED.
8		2 SAND	143.52	36.00	27210	759	
9		4 CHATTS	143.87	36.00	33450	929	
10			142.42	36.00	30900	858	
11			142.47	36.00	31125	865	
12			143.88	36.00	30500	848	
AVG.			143.44	35.97	30439	847	
13	DO.	1 CEMENT	146.70	34.75	30200	870	ONE CORNER SPALLED.
14		2 SAND	145.11	35.62	27880	783	
15		4 CHATTS	146.52	35.63	55250	1579	
16			147.62	36.00	49100	1364	
17			146.69	35.63	40700	1142	
18			145.73	36.00	35200	978	
AVG			146.23	35.61	39722	1119	
19	DO.		114.10	22.24	14550	654	VERY BADLY SPALLED TWO CORNERS.
20		1 CEMENT	112.90	36.00	19050	530	
21		2 SAND	113.41	33.78	15900	471	VERY POROUS SPALLED ON EDGES OF FACES.
22		4 CINDERS	112.73	35.90	22750	620	SPALLED SLIGHTLY AT EDGES.
23			113.20	33.25	19000	571	EDGES AND FACES SLIGHTLY SPALLED
24			113.72	36.00	19500	542	SLIGHTLY SPALLED
AVG			113.36	32.86	18458	565	
25	DO.		140.18	36.00	59400	1650	
26			139.97	35.20	50950	1450	
27		1 CEMENT	142.97	35.25	65650	1862	
28		2 SAND	141.80	35.25	74350	2052	
29		4 CHATTS	142.29	35.25	65250	1851	
30			140.33	36.00	588	1618	
AVG			141.10	35.49	62810	1747	

TABLE II.—Results of Crushing Tests of Cubes Made From Concrete Used in Constructing Reinforced Beams.

ND			SAND SCREENED TO 20 – 30								
2 MOS.	AVERAGE IND.	AVERAGE GEN.	7 DAYS	AVERAGE IND.	AVERAGE GEN.	28 DAYS	AVERAGE IND.	AVERAGE GEN.	2 MOS.	AVERAGE IND.	AVERAGE GEN.
298 286 276 294	292 285	289									
368 395 372 344	381 358	370									
401 362 382 356	381 369	375	242 240 220 206 198 232	235 213	224	287 280 310 303 345 291	292 313	303	319 337 352 363	328 358	343
362 381 330 336	372 333	353	210 227 210 199 212 222	216 217	217	297 285 290 301 319 295	294 305	299	318 306 317 315	312 316	314
386 372 358 397	379 378	379	243 256 252 270 260 254	250 261	256	361 366 355 350 327 362	361 346	358	394 401 382 375	398 379	389
396 391 438 454	393 446	420	257 233 240 212 247 235	243 232	238	295 281 287 321 322 305	288 316	302	316 318 328 346	317 337	327
480 498 520 510	489 515	502	210 206 212 241 233 218	209 231	220	295 331 312 346 315 302	319 321	320	341 318 329 333	330 331	331
377 376 360 322	377 341	359	213 209 212 228 258 242	211 243	227	283 292 303 302 283 284	292 290	291	337 310 309 322	324 315	320
360 347 326 347	354 337	346	215 216 215 211 198 221	215 215	215	299 301 307 292 283 295	302 290	296	336 328 323 329	332 327	329
335 348 298 301	341 299	320	210 213 235 250 226 217	219 231	225	290 314 295 322 309 316	300 317	309	321 337 343 352	329 348	339
481 457 446 461	469 454	462									
438 444 398 418	441 408	425	251 254 260 206 223 220	255 216	236	324 340 328 274 290 292	331 285	308	363 341 309 337	352 323	338
428 433 410 412	431 411	421	212 220 227 223 251 243	220 239	230	302 312 317 305 313 314	310 311	311	335 351 330 327	340 328	334
	389 377	383		225 229	227		302 308	305		370 371	371

on Shown in Table II.

ICH								
SCREENED TO 20–30								
7 DAYS			28DAYS			2 MONTHS		
1270 1125	1189 1155	1172	2300 2250 2200 2413	2275 2307	2291	2428 2450 2475 2565	2464 2520	2492
1550 1533	1585 1503	1544	2350 2378 2493 2488	2364 2491	2428	2380 2363 2828 2795	2372 2812	2592
1448 1300	1374 1332	1353	2363 2275 2675 2063	2319 2369	2344	2410 2428 2528 2488	2419 2508	2464
1398 1150	1412 1182	1297	2300 2038 2225 2188	2169 2207	2188	2343 2450 2178 2173	2397 2176	2287
1083 1128	1067 1121	1095	1944 2225 2000 2025	2085 2015	2050	2223 2075 2063 2075	2149 2069	2109
1288 1218	1257 1224	1241	2123 2000 2158 2270	2062 2214	2138	2450 2478 2438 2432	2464 2435	2450
1000 1050	1044 1000	1022	2410 2538 2460 2748	2474 2604	2539	3363 3388 2713 2600	3376 2657	3016
1238 1205	1223 1199	1211	2253 2203 2453 2054	2227 2254	2241	2718 2930 2600 2560	2828 2580	2704
1000 1125	1057 1153	1105	2260 2400 2350 2522	2330 2436	2383	2910 2870 2860 2840	2990 2850	2897
1178 1115	1166 1130	1148	2163 2260 2075 2178	2212 2126	2169	2453 2488 2315 2328	2471 2322	2397
550 558	625 527	577	1063 993 1190 1203	1028 1197	1114	2038 2020 1990 1968	2029 1979	2004
		1161			2171			2492

tions Shown in Table II.

NAME	LOCATION	SPECIFIC GRAVITY	VOIDS	FINENESS IN PER CENT OF RESIDUE ON SIEVE No. 10	20	30	40	50	80	100	200	PASSED 200
BERKSHIRE	BERKSHIRE MASS	2.64	47.2	0.0	1.0	2.5	6 5	17.4	34.5	16.1	17.1	4.4
CLEVELAND #1	CLEVELAND OHIO	2.61	31.1	41.3	21.9	13.6	9 3	6.2	4.1	1.4	1.3	1.0
CLEVELAND #2	" "	2 66	37.9	2.2	11.4	21.7	26.3	21.5	10.2	1.7	1.1	1.3
COW BAY	NEW YORK	2.67	37.4	7.5	11.9	13.9	20.6	23.1	16.0	2.8	2.6	1.3
JERSEY GRAVEL	PHILADELPHIA	2.66	33.2	8.0	11.0	8.6	10.1	17.6	22.3	9.9	10.4	1.8
KAW RIVER	IOLA KANSAS	2.62	31.5	10.0	16.3	15.6	15.0	15.1	19.3	6.0	2.4	0.4
LIME STONE #1	ST. LOUIS MO.	2.67	35.8	6.6	28.8	14.0	8.5	6.7	6.4	3.7	4.8	20.3
LIME STONE #2	" " "	2.67	44.0	34.7	24.4	10.6	6.6	5.0	4.3	1.8	1.5	11.3
MERAMEC RIVER	" " "	2.59	37.9	0.9	9.2	11.8	22.6	30.1	20.8	3.9	0.6	0.1
MISSISSIPPI RIVER	" " "	2.62	33.2	11.9	18.3	27.8	28.6	6.3	2.8	1.9	1.5	0.9
PLUM ISLAND	BOSTON MASS.	2.66	37.5	4.5	5.6	10.8	20.2	30.7	20.8	3.8	3.0	0.7
TEXAS	DALLAS TEXAS	2.62	34.9	11.6	18.3	15.6	18.3	18.8	13.1	2.5	1.3	0.5
BANK WASHED TORPEDO	CHIGAGO ILL.	2.67	29.6	19.5	16.8	9.5	10.6	14.6	15.8	6.4	5.6	1.2
LAKE TORPEDO	" "	2.66	34.2	9.8	10.2	9.6	11.4	20.3	29.7	6.2	2.3	0.3
BANK SAND	PHILADELPHIA	2.64	41.8	0.9	1.8	6.1	30.1	40.4	17.1	2.3	0.9	0.3
	AVERAGE	2.65	36.5	11.3	13.8	12.8	16.3	18.3	15.8	4.7	3.8	3.1

TABLE III.—Specific Gravity, Percentage of Voids and Granulometric Comp
Sands for Cement Mortar.

NAME	NEAT 1 DAY			AVERAGE INDIVIDUAL	AVERAGE GENERAL	7 DAYS			AVERAGE IND.	AVERAGE GEN.	28 DAYS			AVERAGE IND.	AVERAGE GEN.	2 MOS.		AVERAGE IND.	AVERAGE GEN.	STANDARD OTTOWA SAND 7 DAYS			AVERAGE IND.	AVERAGE GEN.	28 DAYS			AVERAGE IND.	AVERAGE GEN.
BERKSHIRE	228	232	221	227	230	551	526	605	561	581	768	772	770	770	776	898	914	906	887	228	280	284	264	252	386	387	380	384	374
"	233	236	230	233		608	608	584	600		780	792	788	783		854	883	869		291	263	262	239		360	373	365	363	
CLEVELAND #1	375	351		363	358	667	674	663	668	679	860	842	864	855	824	891	884	888	865	232	228	224	228	236	347	343	365	352	340
"	314	390		352		691	675	705	690		831	811	735	792		839	844	842		239	238	254	243		349	304	332	328	
CLEVELAND #2	273	293		283	301	633	588	580	601	598	815	788	820	805	797	810	891	901	893	285	291	290	289	257	460	431	392	428	396
"	304	334		319		558	575	648	594		782	781	800	788		894	873	884		215	228	231	225		365	353	373	364	
COW BAY	286	307		297	293	626	681	632	650	631	761	752	645	719	736	845	823	834	846	248	240	286	257	250	410	375	364	384	366
" "	306	270		288		636	620	578	612		762	745	753	753		845	872	859		260	239	227	242		356	327	358	347	
KAW RIVER	257	250		253	241	595	568	624	596	627	712	840	777	776	767	828	854	841	830	265	262	265	264	256	398	387	420	402	402
	228	230		229		655	640	685	660		723	771	779	758		813	824	819		259	254	231	248		385	419	402	402	
LIMESTONE #1.																													
"																													
LIMESTONE #2.																													
"																													
MERAMEC	292	285		288	308	584	593	612	600	620	675	712	650	679	749	825	840	835	861	273	262	276	270	240	390	363	382	378	389
"	323	333		328		603	633	682	639		832	806	820	819		899	872	886		203	208	220	210		404	417	386	399	
MISSISSIPPI	305	293		299	314	653	610	621	628	618	604	680	717	667	720	788	807	798	791	240	252	256	249	226	366	346	393	368	360
"	309	347		328		583	571	669	608		730	789	798	772		863	705	784		192	195	223	203		350	362	342	351	
PLUM ISLAND	278	286		282	263	672	648	640	653	626	768	832	753	784	788	798	831	814	822	252	238	237	242	249	341	390	397	376	377
" "	241	245		243		591	570	639	600		753	798	824	792		818	844	831		251	255	289	255		384	378	370	377	
TEXAS	185	180		183	199	642	639	654	645	633	785	785	750	773	764	785	806	801	799	260	277	240	259	250	449	373	372	388	379
"	205	206		206		616	675	572	621		783	730	752	755		778	793	786		218	246	255	240		355	363	363	360	
WASHED BANK TORPEDO	265	293		289	281	595	546	649	597	628	770	778	772	777	773	800	812	806	803	262	279	265	275	265	378	363	400	380	386
	261	283		272		615	643	715	658		764	788	752	768		807	793	805		240	282	252	258		397	510	410	392	
LAKE TORPEDO	273	320		297	308	571	630	638	620	619	634	680	760	693	746	834	815	825	850	238	244	233	237	240	378	379	398	385	384
" "	333	302		318		668	541	641	617		803	802	790	798		875	872	874		247	252	231	243		412	375	372	386	
AVERAGES				274	277				621	622				761	770			841	840				263	251				391	380
				280					623					779				838					240					368	

TABLE IV.—Comparative Tensile Strength of Mortars Ma

NAME	COMPRESSIVE STRENGTH OTTOWA STANDARD 7 DAYS				28 DAYS				2 MONTHS				UNSC[REENED] 7 DAYS			
BERKSHIRE	1425	1655	1540	1395	2428	2325	2377	2350	2275	2213	2244	2247	700	688	694	542
"	1225	1275	1250		2250	2393	2323		2275	2225	2250		388	390	389	
CLEVELAND #1	1275	1280	1278	1267	2758	2653	2706	2228	3440	2955	3198	2867	1458	1475	1467	1341
"	1250	1260	1255		1725	1775	1750		2295	2775	2535		1043	1388	1215	
CLEVELAND #2	1308	1285	1297	1311	2208	2225	2217	2171	2463	2680	2572	2452	938	925	932	1066
"	1275	1375	1325		2138	2113	2126		2275	2388	2331		1200	1200	1200	
COW BAY	2885	2703	2794	2039	3513	3738	3626	3185	4038	3975	4007	3757	2030	2175	2103	1632
" "	1225	1343	1294		2688	2800	2744		3450	3563	3507		1019	1303	1161	
KAW RIVER	1300	1227	1263	1458	2138	2125	2131	2053	2540	2463	2502	2483	1495	1475	1485	1540
"	1698	1608	1653		1950	2000	1975		2478	2450	2464		1688	1500	1594	
LIMESTONE #1	1380	1353	1367	1389	2188	2178	2183	2219	2658	2530	2594	2719	2613	2550	2582	2557
"	1420	1403	1412		2275	2235	2255		2895	2793	2844		2663	2400	2532	
LIMESTONE #2													958	935	947	1005
"													975	1150	1163	
MERAMEC	1725	1625	1475	1369	2975	2883	2929	2765	3663	3575	3619	3403	1275	1375	1325	1250
"	1250	1275	1263		2638	2563	2601		3300	3075	3188		1200	1150	1175	
MISSISSIPPI	1155	1216	1186	1244	2723	2670	2697	3046	2938	3125	3062	3375	1553	1583	1568	1519
"	1358	1250	1302		3213	3575	3394		3625	3250	3688		1450	1488	1469	
PLUM ISLAND	1368	1568	1468	1459	2475	2688	2581	2457	3045	3263	3154	2954	1154	1038	1096	1043
" "	1500	1400	1450		2388	2275	2332		2785	2725	2755		1013	968	991	
TEXAS	1205	1240	1223	1118	2188	2510	2349	2176	3163	2820	2992	2788	1300	1233	1267	1446
"	930	1095	1013		2075	1930	2003		2478	2690	2584		1500	1748	1624	
WASHED BANK TORPEDO	1195	1083	1139	1153	3380	2700	3040	2767	3880	3593	3737	3225	1413	1355	1384	1554
" " "	1055	1280	1168		2313	2675	2494		2675	2750	2713		1723	1725	1724	
JERSEY GRAVEL	1758	1695	1727	1431	3705	3480	3593	3103	3900	3938	3919	3590	1000	1143	1072	1052
	1200	1070	1135		2650	2575	2613		3095	3428	3262		955	1108	1032	
PHILA. BANK SAND	1180	1220	1200	1105	2408	2525	2467	2392	2750	2718	2734	2626	503	488	496	475
" " "	1088	950	1019		2308	2328	2318		2540	2498	2519		450	455	453	
AVERAGE				1364				2532				2960				1288

TABLE V.—Comparative Compressive Strengths of Mortars M

REMARKS
WHITE
BROWN
LIGHT BROWN
" "
YELLOWISH
LIGHT BROWN
WHITE
GREY
LIGHT YELLOW
CHOCOLATE COLOR
YELLOWISH
YELLOWISH BROWN
" "
YELLOWISH
BROWN
AVERAGE

sition of Various

R SQUARE INCH

S.	AVERAGE IND.	AVERAGE GEN.	UNSCREENED SAND 7 DAYS	AVERAGE IND.	AVERAGE GEN.	28 DAYS	AVERAGE IND.	AVERAGE GEN.	2 MOS.	AVERAGE IND.	AVERAGE GEN.	SAND SCREENED TO 20-30 7 DAYS	AVERAGE IND.	AVERAGE GEN.	28 DAYS	AVERAGE IND.	AVERAGE GEN.	2 MOS.	AVERAGE IND.	AVERAGE GEN.
33 14	431 405	416	139 136 138 138 120 122	138 127	133	215 216 224 200 210 214	218 208	213	298 286 276 294	292 265	289									
93 91	391 380	386	296 302 266 221 228 239	288 229	259	349 343 360 300 291 340	351 310	331	368 395 372 344	381 358	370									
85 31	479 412	446	220 223 227 188 198 206	223 194	209	320 370 320 340 338 330	337 336	337	401 362 382 356	381 369	375	242 240 220 208 198 232	235 213	224	287 280 310 303 345 291	292 313	303	319 337 352 363	328 358	343
12 72	419 378	398	273 252 249 244 250 235	258 243	251	341 373 353 334 315 329	356 326	341	362 381 330 336	372 333	353	210 227 210 199 212 222	216 217	217	297 295 290 301 319 295	294 305	299	318 306 317 315	312 316	314
58 42	451 455	453	302 291 275 244 240 266	289 257	273	340 355 329 336 380 360	341 359	350	386 372 358 397	378 376	379	243 256 252 270 250 254	250 261	256	361 366 355 350 327 362	361 346	358	384 401 382 375	398 379	389
			295 297 306 255 250 242	299 246	273	372 370 365 402 388 435	369 408	389	396 391 438 454	393 446	420	257 233 240 212 247 235	243 232	238	295 281 287 321 322 305	288 316	302	316 318 328 346	317 337	327
			260 273 236 195 243 257	256 232	244	365 360 365 450 447 452	363 450	407	480 498 520 510	489 515	502	210 206 212 241 233 218	209 231	220	295 331 312 344 315 302	319 321	320	341 318 329 333	330 331	331
02 12	408 401	405	260 278 250 224 232 233	263 230	247	315 390 351 279 280 298	352 286	319	377 376 360 322	377 341	359	213 209 212 228 258 242	211 243	227	283 292 303 302 283 284	292 290	291	337 310 309 322	324 315	320
37 41	428 455	442	250 240 241 240 260 243	244 248	246	333 342 328 332 320 314	334 322	328	360 347 326 347	354 337	346	215 216 215 211 198 221	215 215	215	299 301 307 292 283 295	302 290	296	336 328 323 329	332 327	329
59 54	461 460	461	200 182 218 180 185 183	200 183	182	252 225 248 202 220 211	242 211	227	335 348 298 301	341 299	320	210 213 235 250 226 217	219 231	225	280 314 295 322 309 316	300 317	309	321 337 343 352	329 348	339
87 27	477 425	451	360 303 322 252 254 282	328 263	286	449 420 415 387 323 402	428 404	416	481 457 446 461	469 484	462									
32 16	415 418	417	360 340 300 244 253 243	317 247	282	478 420 392 345 352 392	420 363	397	438 444 398 418	441 408	425	231 254 260 206 223 220	255 216	236	324 340 328 274 290 292	331 285	308	363 341 309 337	352 323	338
18 36	414 416	415	298 336 317 258 279 252	317 263	219	399 401 391 391 387 389	397 389	393	428 433 410 412	431 411	421	212 220 227 223 251 243	220 229	230	302 312 317 305 313 314	310 311	311	335 351 330 327	340 326	334
	437 423	430		260 226	243		342 336	338		389 377	383		225 229	227		302 308	305		370 371	371

e of Sands of the Composition Shown in Table II.

N LBS. PER SQ. INCH

EENED 28 DAYS			2 MONTHS			SCREENED TO 20-30 7 DAYS			28 DAYS			2 MONTHS		
1000 838	932 894	913	1500 1545 1490 1498	1523 1494	1508									
2055 1350	1970 1388	1679	3025 2523 2313 2478	2774 2396	2572									
1688 1300	1692 1350	1521	2850 2663 2453 2483	2757 2468	2613	1108 1270 1185 1125	1189 1155	1172	2300 2250 2200 2413	2275 2307	2291	2428 2450 2475 2565	2464 2520	2492
2825 2025	2856 2238	2547	3578 3390 2800 2778	3484 2789	3137	1620 1550 1473 1533	1585 1503	1544	2350 2378 2493 2488	2364 2491	2428	2380 2363 2828 2795	2372 2812	2592
2175 1863	2319 1882	2100	2415 2575 2283 2218	2495 2251	2373	1300 1448 1363 1300	1374 1332	1353	2363 2275 2675 2063	2319 2369	2344	2410 2428 2528 2488	2419 2508	2464
3438 3850	3376 3544	3460	2715 3628 3775 3695	3672 3735	3704	1425 1398 1213 1150	1412 1182	1297	2300 2038 2225 2188	2169 2207	2188	2343 2450 2178 2173	2397 2176	2287
1188 1575	1150 1475	1313	1625 1678 1835 1670	1652 1753	1703	1053 1083 1113 1128	1067 1121	1095	1944 2225 2000 2025	2085 2015	2050	2223 2075 2063 2075	2149 2069	2109
2315 1705	2295 1738	2017	2300 2363 2425 2288	2332 2357	2345	1225 1288 1230 1218	1257 1224	1241	2123 2000 2158 2270	2062 2214	2138	2450 2478 2438 2432	2464 2435	2450
3748 4125	3776 3773	3775	3875 4138 4675 4413	4006 4544	4275	1088 1000 950 1050	1044 1000	1022	2410 2538 2460 2748	2474 2604	2539	3363 3388 2713 2600	3376 2657	3016
1518 1500	1577 1550	1564	2750 2495 2533 2468	2623 2501	2562	1208 1238 1193 1205	1223 1199	1211	2253 2203 2453 2054	2227 2254	2241	2718 2930 2600 2560	2828 2580	2704
1928 2308	1827 2673	2250	2378 2405 3538 2475	2392 3006	2699									
2280 3600	2447 3475	2961	3158 3145 3150 2800	3152 2975	3064	1113 1000 1180 1125	1057 1153	1105	2260 2400 2350 2522	2330 2436	2383	2910 2870 2860 2840	2990 2850	2897
643 363	1753 1494	1626	2385 2428 2208 2235	2407 2222	2315	1153 1178 1145 1115	1166 1130	1148	2163 2260 2075 2178	2212 2126	2169	2453 2488 2315 2328	2471 2322	2397
1020 763	1029 771	900	1713 1775 1483 1543	1744 1513	1629	700 550 495 558	625 527	577	1063 993 1190 1203	1028 1197	1114	2038 2020 1990 1968	2029 1979	2004
		2045			2607			1161			2171			2492

de of Sands of the Compositions Shown in Table II.

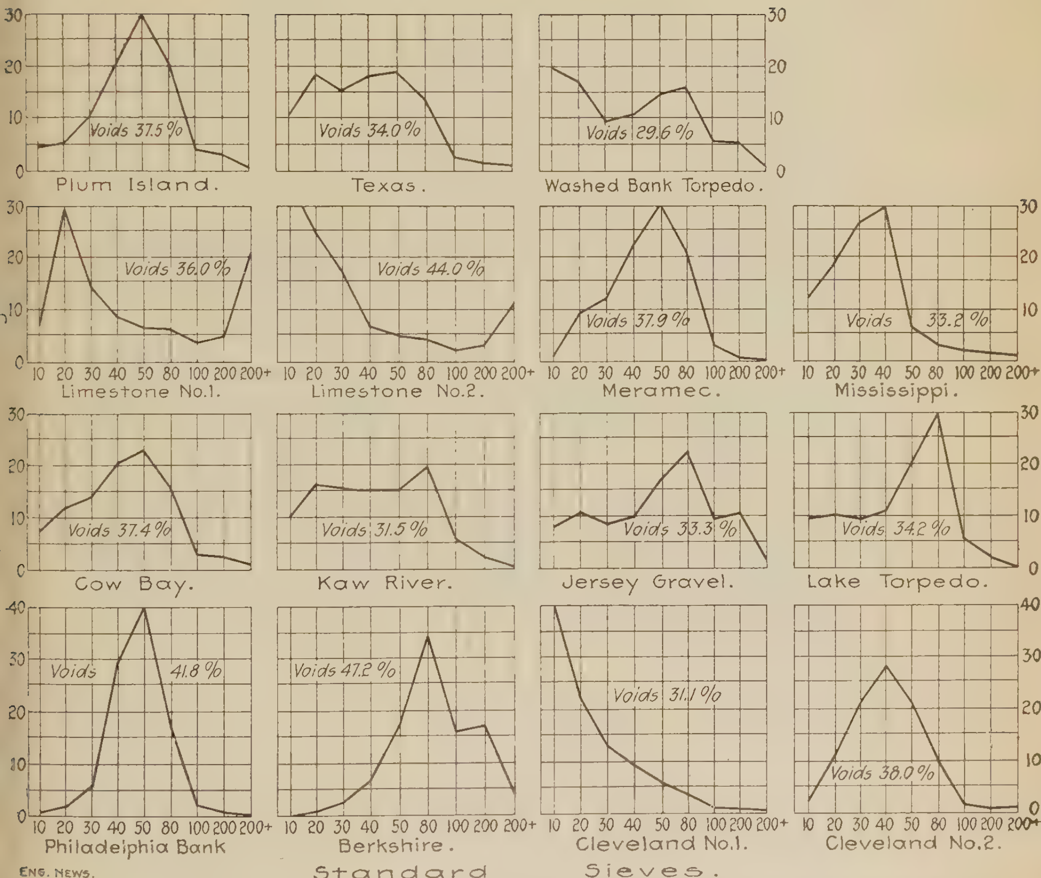


Fig. 5.—Diagrams Showing Granulometric Analysis of Various Sands for Cement Mortars.

of fine material passing the number 200 sieve and even of material designated as "silt" except in the case of the two limestones. This fine material in all cases being inorganic, and should not, therefore, be classed as "loam"—a term in common use. The term "loam" is a much abused one, is rarely ever used correctly, as "loam" properly so called is a vegetable mold and has a decided weakening effect on the strength of any material in which cement is used as a binder. Fine inorganic material, if not present in excessive proportion, enhances the strength of mortars or

FIG. 6.—Views of Reinforced Concrete Beams 1, 2, 3 and 4 After Failure.

concretes, as it tends to lessen the percentage of voids thereby reducing the quantity of cement required to fill the voids.

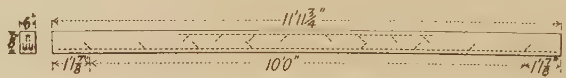
In addition to the above tests, four experimental beams were tested in the laboratory; three of these (two of rectangular and one of T-section) were made according to the Hennebique system; and the other, also rectangular in section, according to the Kahn system. The beams of rectangular section were made under identical conditions and were designed to carry the same load using the same percentage of steel reinforcement. These beams were made in the open air and were not wetted after being made

and the forms were removed just before the tests were made, at the end of 60 days. The beams remained in the open air during that time and were not moved until tested.

Test cubes were made of the concrete from which the beams were cast and the results of these tests may be found in Table II from 25 to 30 inclusive.,

Fig. 6 shows the condition of the beams after testing; the photographs are not, however, sufficiently clear to show the location of the hair cracks. The poor quality of the concrete which will be alluded to later, caused the beams to fall without developing the full strength of the steel in tension, although in both the Hennebique and Kahn beams the compressive resistance of the top of the beam was materially increased by the steel reinforcement. In the latter beam the results would probably have been higher had the top reinforcing bar run the full length of the beam, as it will be observed that the concrete failed around the ends of this bar.

The following is the result of the tests of these beams in the order in which they were tested:

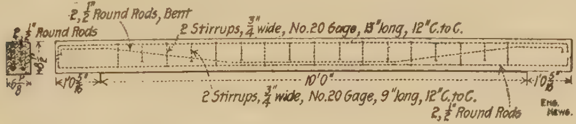


BEAM 1, KAHN SYSTEM.—Length over all, 11 ft. 11¾ ins.; clear span, 10 ft.; breadth, 6½ ins.; depth over all, 8¼ ins.; depth to center of steel, 7¼ ins.; compressive strength concrete, 60 days, 1,747 lbs. per sq. in.; weight of beam, 593 lbs.; mixture, 1 : 2 : 4; reinforcement in top, one ½-in, Kahn bar 9 ft. long; reinforcement in bottom, two ½-in. Kahn bars 11 ft. 11¾ ins. long.

Steel in tension	1.59%
Steel in compression	.80%
Total steel	2.39%

Loads. lbs.	Deflection. in.	Remarks.
1350	3-32	
2350	1-8	
3350	5-16	Crack appeared on right under end of top of reinforcing bar.
4350	3-8	
5350	15-32	Crack appeared on left under end of top of reinforcing bar.

Loads. lbs.	Deflection. In.	Remarks.
6350	17-32	
7350	5-8	
7770	7-8	Failed by concrete crushing around ends of top reinforcing bar. Concrete buckled at the ends of top bar.



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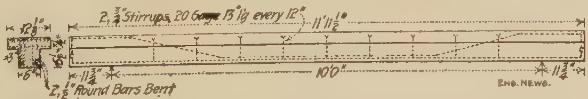
BEAM 2, HENNEBIQUE SYSTEM.—Length over all, 12 ft. ⅝ in.; clear span, 10 ft.; breadth, 6⅝ ins.; depth over all, 8½ ins.; depth to center of steel, 7½ ins.; weight of beam, 620 lbs.; mixture, 1:2:4; compressive strength of beam, 60 days, 1,747 lbs. per sq. in.

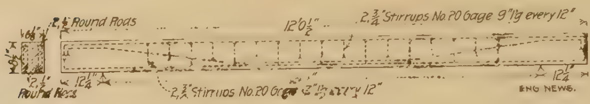
Steel in tension	1.60%
Steel in compression	.80%
Total steel	2.40%

Loads lbs.	Deflection. in.	Remarks.
1850	3-32	
2350	1-8	
4350	5-16	
5350	7-16	
6350	9-16	Hair cracks appeared on either side of center, very faint.
7650	13-16	
8150	15-16	Cracks became more general.
8450	1-13-16	Failed by concrete buckling in center of beam.



BEAM 3, HENNEBIQUE SYSTEM.—Length over all, 11 ft. 11½ ins.; clear span, 10 ft.; breadth, 12⅛ ins.; depth over all, 9 ins.; depth to center of steel, 7½ ins.; weight of beam, 876 lbs.; mixture, 1:2:4; strength of beam, 60 days, 1,747 lbs. per sq. in.

Loads. lbs.	Deflection. in.	Remarks.
2350	1-8	
4350	5-32	
6350	3-8	
7950	15-32	First hair cracks appeared in center.
8350	9-16	
8750	7-8	Failed by concrete crushing at top in center of beam



BEAM 4, HENNEBIQUE SYSTEM.—Length over all, 12 ft. ½ in.; clear span, 10 ft.; breadth, 6⅛ ins.; depth over all, 8½ ins.; depth to center steel, 7½ ins.; weight of beam, 614 lbs.; mixture, 1: 2: 4; compressive strength, 60 days, 1,747 lbs. per sq. in.

Steel in tension	1.60%
Steel in compression	.80%
Total	2.40%

Loads. lbs.	Deflection. in.	Remarks.
1350	1-16	
2350	1-8	
3350	3-16	
4350	7-32	
5350	3-8	
6350	1-2	Faint hair cracks on either side, center very faint.
7350	19-32	
8350	13-16	
8650	1	Failure by concrete buckling at top in center.

In the space adjacent to the Exhibit building there had been planned an elaborate series of test beams built according to the various systems in use in this country. Unfortunately, the exhibit was completed so late that it was impossible to stir up sufficient interest to carry out an elaborate program. Besides, there were no funds available for such experiments, and the expenses connected with the tests which were made were very generously borne by the Trussed Concrete Steel Co., of Detroit, Mich., and The Hennebique Construction Co., of New York, to whom the writer wishes to express his thorough appreciation and thanks for the interest taken and the assistance rendered by them in the experiments.

The tests in question consisted in reinforced concrete beams and floor slabs of 15 ft. span and a cantilever. Simultaneous with the making of the test beams 6-in. cubes were made from the concrete which was used in making the beam and floor slabs. These results of these tests are found in Table II, Pl. VI.

The chatts which were used were a calcareous chert, all of which passed a No. 10 screen. There are two varieties of chatts, a hard silicious chert which comes from Joplin, Mo., and the soft calcareous chert which comes from Bonne Terre, Mo. This material is the refuse from the lead mines and as it is relatively cheap it is extensively used in St. Louis and vicinity. The chatts used was of the calcareous variety and were quite soft and friable, having a low compressive strength and therefore making a concrete correspondingly poor.

It was for this reason that the beams tested failed in many cases under a small load before the strength of the steel was developed.

It will be noted that the cinder concrete gave correspondingly low results. The cinder was clean and of a better quality than is generally used—although it contained a large quantity of unburned coal. The strength of the concrete in which it was used was about one-half of that of a good stone concrete. The modulus of elasticity was about 1,500,000 in the concrete made with chatts and 500,000 for the cinder concrete—values materially lower than are usually quoted.

These tests show how important it is to have a hard aggregate in order to secure a strong concrete. An important feature generally overlooked in tests of concrete is the compressive strength of the aggregate itself. If a test of the aggregate was made it would serve as a basis for comparing the compressive resistance of concrete and would indicate whether the difference was due to differences in the strength of the aggregate or was due to the mixing or to character of the other aggregates.

The concrete for the beams and floor slabs was mixed by hand in the proportion of one part Portland cement, two parts Mississippi River sand and four parts chatts; wooden forms were used and were thoroughly wetted before the sloppy wet concrete was deposited in them. The concrete was not subsequently wetted and the forms were removed at the end of ten days. They remained in air, unprotected, and were not handled until tested at the end of about 60 days, when they were loaded to destruction with pig iron. This method is a slow, laborious process requiring the exercise of great care in loading so as to maintain the center of gravity of the load over the center of the beam, but there were no

other means available for testing these beams of such large size and span.

The overturning which occurred in the case of A and B was produced by the unequal compression of the earth under the bearings supporting the beams. Possibly, this will also account for the shearing of the overhanging un-reinforced slab in the T beam F. The ground on which the beams were built had been filled in with the refuse staff, scaffolding, etc., from the Exposition buildings and in proportioning the bearing area insufficient allowance was made for the compressibility of this filling.

In order to avoid arching of the pig iron, through the deflection of the beam under load, the pig iron was placed in piles and sufficient clearance was left between the piles so that the deflection would not bring them into contact. Where the load required to break the beam is large, these piles are quite high (for A and B they were 5 ft.), the piling of the pig becomes slower and the maintenance of the equilibrium much more difficult as the height increases. The rate of loading varied from 50 lbs. to 150 lbs. per minute. The deflections were measured at the center from a string stretched taut over two wire nails in the side of the beam immediately over the edge of the support and in the center line of the bottom reinforcing steel.

The following are the results of the tests of these beams:

BEAM F.—Built Sept. 13; tested Dec. 1, 1905. Length over all, 17 ft.; clear span, 15 ft.; breadth at base, 8 ins.; at top, 18 ins.; depth over all, 13½ ins.; depth to center of steel, 11½ ins.; reinforcement in bottom, two 1-in. round bars, with one 1-in. round bar just above; mixture, 1:2:4; weight of beam, 2,529 lbs., compressive strength of concrete, 1,740 lbs. per sq. in., per cent. of steel, 1.63, area of steel, 2.35 sq. ins.

Time.	Loads. lbs.	Deflection. in.	Remarks.
10.50 A. M.	3656	3-16	
11.35 "	6877	3-16	
11.50 "	8997	1-4	
12.00 Noon.	10807		
1.05 P. M.	14105	7-16	
1.40 "	18898	9-16	Two hair cracks 1 ft. off center line, either side.
	20166		Failed.

Bars sliding as beam collapsed, Fig. 7. The slab sheared off on one side as will be seen, this was probably due to lack of uniformity of

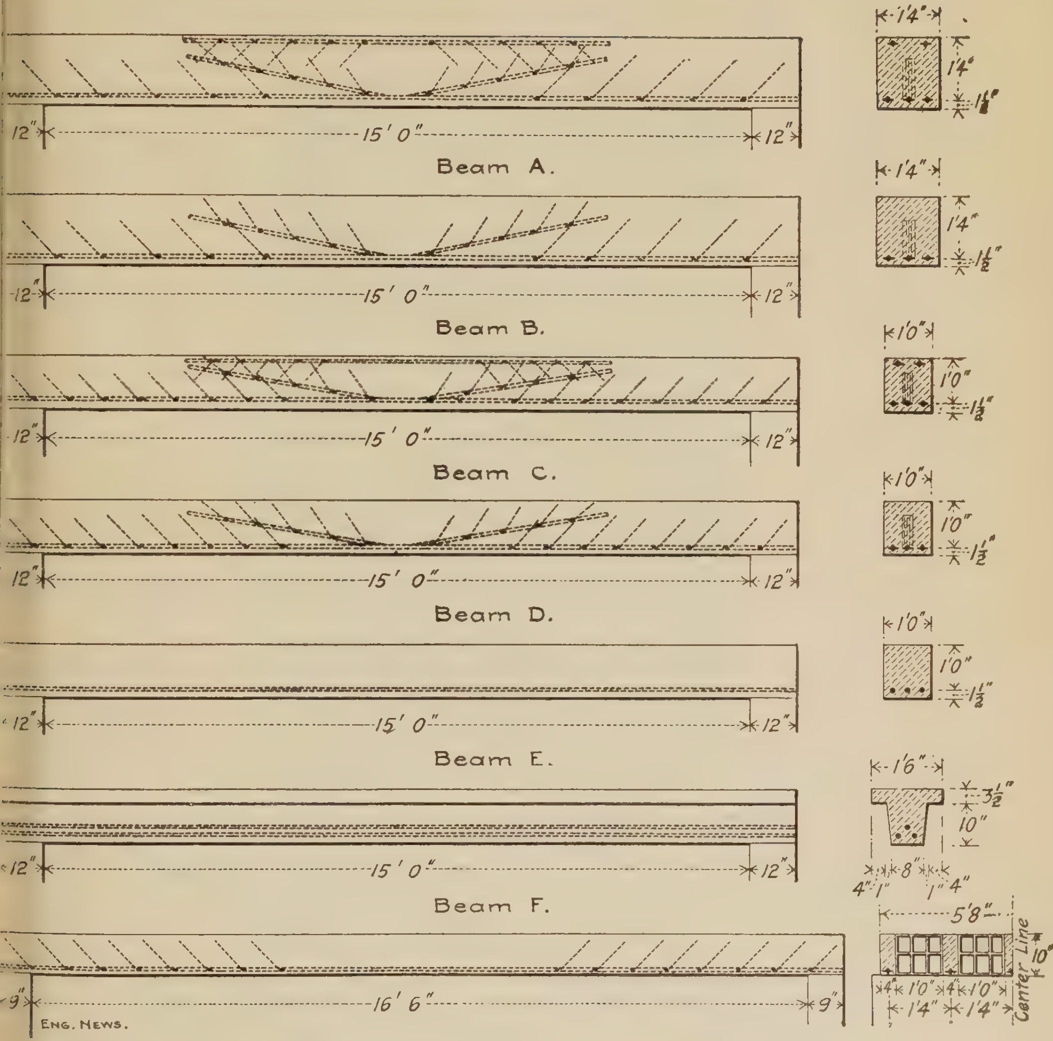


FIG. 8.—Diagrams of Test Beams and Floors Showing Dimensions and Reinforcement.

load. The bars did not slip until the beam collapsed. There was no reinforcing in the slab. The dimensions of beam and other information can be obtained from Fig 8, Pl. IX.

BEAM E.—Built Sept. 13; tested, Dec. 1, 1905. Length over all, 17 ft.; clear span, 15 ft.; breadth, 12 ins.; depth over all, 13½ ins.; depth to center of steel, 12 ins.; weight of beam, 2,677 lbs.; mixture, 1:2:4;

FIG. 7.—View of End of Beam E Showing Shearing Off of Slab and Sliding of Reinforcing Rods.

compressive strength of concrete, 1,740 lbs. per sq. in.; reinforcement in bottom, three 1-in. round bars 17 ft. long; area of steel, 2.35 sq. ins.; per cent, 1.63.

Time.	Loads. lbs. sq. in.	Deflection. in.	Remarks.
9.00 A. M.	16510	9-32	Deflection not noticed before 1,000 lbs.
12.00 Noon.	20166	11-32	
	24612	15-32	
5 30 P. M.	26460	1-2	

Time.	Loads. lbs. sq. in.	Deflection. in	Remarks.
Dec. 2d.			
8.30 A. M.	33198	21-32	
8.30 "	26460	11-16	Two hair cracks, one on either side of the center line.
	33108		Failed.

A series of vertical cracks appeared until the beam failed suddenly by horizontal shear at one end entirely. Bars again slipped as beam collapsed. Dimensions of beam given in Fig. 8, Pl. IX. Fig. 9 shows beam after failure.

FIG. 9.—View of End of Beam E Showing Sliding of Reinforcement.

BEAM D.—Built Sept. 13; tested, Dec. 2, 3, 1905; Length over all, 17 ft.; clear span, 15 ft.; breadth, 12 ins.; depth over all, $13\frac{1}{2}$ ins.; depth to center of steel, 12 ins.; weight of beam, 2,677 lbs.; mixture, 1:2:4; reinforcement in bottom, two $\frac{3}{4}$-in. Kahn bars 17 ft. long; reinforcement in bottom, one $\frac{3}{4}$-in. Kahn bar 9 ft. long, bent up slightly; area steel in tension, 2.34 sq. ins.; per cent. of steel, 1.63; compressive strength of concrete, 1,740 lbs. per sq. in.

Time.	Loads. lbs.	Deflection. ins.	Remarks.
Dec. 2d.			
3.30 P. M.	6479	1-16	
3.50 "	8461	3-32	
5.00 "	11806	1-4	
5.30 "	15033	11-32	
Dec. 3d.			
8.30 A. M.	15033	11-16	
8.55 "	20732	3-8	
9.30 "	23476	1-2	
10.30 "	27800	11-16	
11.30 "	30719	1 in.	
11.45 "	32663	$1\frac{3}{4}$ in.	
11.50 "	32663		Failed slowly 4 ft. 6 ins. from each end of beam.

For dimensions, etc., see Fig. 5.

BEAM C.—Built Sept. 12; tested, Dec. 3, 4, 5, 1905. Length over all, 17 ft.; clear span, 15 ft.; breadth, 12 ins.; depth over all, $13\frac{1}{2}$ ins.; depth to center of steel, 12 ins.; weight of beam, 2,677 lbs.; mixture, 1 : 2 : 4; reinforcement in bottom, two $\frac{3}{4}$-in. Kahn bars 17 ft. long; reinforcement in bottom, one $\frac{3}{4}$-in Kahn bar 9 ft. long, bent up slightly; reinforcement in top, two $\frac{1}{2}$-in. Kahn bars 9 ft. inverted; area of steel in tension, 2.34 sq. ins.; area of steel in compression, .76 sq. in.; total area of steel, 3.10 sq. ins.; per cent. of steel, 2.15; compressive strength of concrete, 1,740 lbs. per sq. in.

Time.	Load. lbs.	Deflection. ins.	Remarks.
Dec. 3.			
3.10 P. M.	5629	1-32	
3.50 "	11398	3-16	
4.20 "	15287	3-8	
Dec. 5.	Nothing done.	Sunday.	
Dec. 6.			
8.00 A. M.	15287	3-8	
8.30 "	18100	3-8	
9.00 "	21688	15-32	Hair cracks appearing.
9.30 "	24058	5-8	
9.55 "	29943	7-8	
10.05 "	28934	1	
10.10 "	29914	$1\frac{1}{4}$	
10.15 "	30878	1–11-16	
10.25 "	....		Failed.

Dimensions, etc., shown in Fig. 5.

BEAM B.—Built Sept. 12; tested, Dec. 5, 6, 1905. Length over all, 17 ft.; clear span, 15 ft.; breadth, 16 ins.; depth over all, 17½ ins.; depth to center of steel, 16 ins.; reinforcement in bottom, two 1-in. Kahn bars 17 ft. long; reinforcement in bottom, one ¾-in. Kahn bar 9 ft. long, bent slightly upwards; area of steel, 3.62 sq. ins. or 1.41%; weight of beam, 4,600 lbs.; mixture, 1:2:4; compressive strength of concrete, 1,740 lbs. per sq. in.

Time.	Load. lbs.	Deflection. ins.	Remarks.
Dec. 5.			
2.00 P. M.	10417	1-16	
2.30 "	15189	3-32	
3.20 "	22802	7-32	
4.10 "	27607	9-32	
4.45 "	31487	11-32	One hair crack on bottom of beam under each bent bar.
Dec. 6.			
8.30 A. M.	31487	11-32	
9.35 "	33403	11-32	Two more hair cracks appeared.
10.50 "	38190	11-32	
12.45 P. M.	45082	15-32	
1.30 "	47817	3-4	Two more hair cracks appeared nearer bearings.
2.10 "	50000	7-8	
3.10 "	54735	1-11-32	
	55727	1- 7-16	
	56712	1-19-32	
3.50 "	57696	1-11-16	
	58675	1-31-32	
4.15 "	59906	2	
5.00 "	60911	2-11-32	Beam overturned.

BEAM A.—Built Sept. 13, 1904; tested, Dec. 7–14, 1905. Length over all, 17 ft.; clear span, 15 ft.; breadth, 16 ins.; depth over all, 17½ ins.; depth to center of steel, 16 ins.; reinforcement in bottom, two 1-in. Kahn bars 17 ft. long; reinforcement in center, one ¾-in. Kahn bar 9 ft. long, bent up slightly; reinforcement in top, two ¾-in. Kahn bars 9 ft. long, inverted; weight of beam, 4,600 lbs.; mixture, 1:2:4; area steel in tension, 3.62 or 1.41%; area steel in compression, 1.56 or .60% ; total steel, 5.18 or 2.10%; compressive strength of concrete, 1,740 lbs. per sq. in.

Time.	Loads. lbs.	Deflection. in.	Remarks.
Dec. 7:			
9.25 A. M.			Started.
10.45 "	10168	1-16	
11.40 "	15937	3-32	

Time.	Loads. lbs.	Deflection. in.	Remarks.
2.25 P. M.	20769	5-32	
3.10 "	25632	3-16	
3.25 "	27617	3-16	
3.55 "	31548	3-16	
4.30 "	33561	3-16	
4.45 "	35477	7-32	
5.00 "	37458	7-32	Two faint hair cracks, one at each end of bent bar in center; beam started to overturn, bearings sinking unequally.

Dec. 8: Unloaded and straightened.

No deflection observable, then began loading.

Dec. 9:

8.30 A. M.	37458	7-32	
9.45 "	40839	7-32	
10.35 "	44723	1-4	Four hair cracks (2 more) on each side of center.
11.25 "	50000	5-16	Rain stopped, loading beam overturned, due to unequal settling of foundations.
	52693		

Dec. 11:

	52962	3-32	Set in beam.
	54945	13-32	
	60856	5-8	Beam overturned.

Foundations again settling unequally, beam straightened, one hair crack in center 2, 3 ft. 6 ins. on either side of center of beam; ⅜-in deflection set in beam. Foundations releveled bearing area increased and beam reloaded.

Dec. 12: Sunday—Nothing done.

Dec. 13:

11.15 A. M.	60856	3-8	Set in beam.

Several hair cracks from top ⅛-in. opening traveling off in both directions horizontally, middle each 8½ ins. from top.

	63811		Two more hair cracks appeared on either side of center line.

Time.	Loads. lbs.	Deflection. in.	Remarks
	66021	3-4	
3.45 P. M.	74941	1-1-8	
	75000		One crack 18 ins. from center line, 9 ins. from top. One crack 36 ins. from 11 ins. from One crack 56 ins. from 7 ins. from
5.00 P. M.	80000	1-3-8	

Time.	Loads. lbs.	Deflection. in.	Remarks.
Dec. 14:			
8.00 A. M.	80000	1-3-4	
	81010	1-13-16	
	82005	1-13-16	
	83005	1- 7-8	
	83977	1- 7-8	
11.30 A. M.	85400	1- 7-8	
12.00 Noon.	87385	2- 1-32	
1.25 P. M.	90362	2- 5-8	
2.15 "	93269	3- 1-8	
2.30 "	94074	3- 5-16	
2.40 "	94512		Failed.
Weight beam	4600		
Total load,	99112		

FIG. 10.—View of Kahn Beam A Under Load

Kahn System Hollow Tile Floor Construction.—Built Sept. 21, tested Nov. 30, Dec. 1, 2, 1905. Length over all, 18 ft. Clear span 16 ft. 6 ins. Width, 5 ft. 8 ins. Depth, 10 ins. Tile, 10 x 12 ins. Beam joists, five, 4 x 10 ins., 18 ft. long, 1′ 4″ centers.

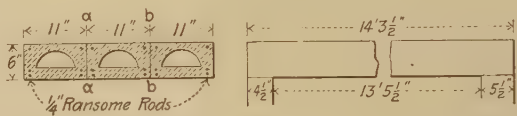
Reinforcement, each joist, one $\frac{3}{4}$-in. Kahn bar, 18 ft. long. Mixture, 1 : 3 : 5. Area steel, each joist, 0.78 in. or 2.30 per cent. Weight of slab, 5,800-lbs.

FIG. 11.—View of Kahn Hollow Tile Floor After Failure.

Time.	Loads. lbs.	Deflection. ins.		Remarks.
Nov. 30:				
4.10 P. M.	12457	n. 3-32	s. 3-32	
4.45 "	18300	1-8	3-32	
5.10 "	22200	1-2	3-8	Hair cracks across center exactly.
5.30 "	25132	5-8	3-8	
Dec. 1:				
8.30 A. M.	25132	3-4	9-16	
5.30 "	25132	3-4	21-32	
Dec. 2:				
8.30 A. M.	25132	3-4	23-32	
11.25 "	25132	25-32	3-4	
11.50 "	34634	2-1-2		Two vertical cracks appeared 3 ins. off center line on either side.

11.55 A. M. 35611 Concrete commenced to crush on top over last cracks loading stopped, beam kept cracking and slowly deflected until it failed at 12.15 (20 minutes) with center cracks opening up and another 7 ft. off centre line concrete at center crushing out and a crack running along line of steel from center to right three feet. Breaking load 500 lbs. per sq. foot. The dimensions of slab are shown in Fig. 8, Pl. IX. Fig. 11 shows floor after failure.

Siegwart Floor.—Length over all 14 ft. 3½ ins., clear span 13 ft. 5½ ins., depth 6 ins., width of slab 33 ins.



Time.	Load. lbs.	Deflection. in.	Remarks.
8.30 A. M.	2901	1-8	
9.15 "	5484	5-16	
9.25 "	8409	1-2	Hair cracks well distributed along bottom beam.
	10378	13-16	
	11366	7-8	
10.05 "	15313	1-23-32	
	16284	2-3-4	
10.15 "	16831		Failed.

This floor slab was composed of beams made according to Siegwart System; in above sketch the slab is seen to be composed of three slabs 11 x 6 ins. in section, and reinforced with rods according to Hennebique System without shear straps. The beams are cast around cores (core openings shown in sketch), the steel being placed in position and the concrete cast around it; the cores are withdrawn and the beams feathered apart at the points indicated. These beams were made in New York, and were shipped by express when 60 days old to the exhibit, where they were placed in position and the joints grouted. A load of bags of sand was placed on the floor (100 lbs. per sq. ft.) and remained there until the close of the Exposition, when it was loaded with pig iron to destruction, the beams being about 6 months old. The idea of this system is to make the beams for certain loads and spans and carry them in stock as steel I-beams are carried, shipping on order.

Cantilever.—This is shown in Fig. 12 and was built to illustrate the flexibility of reinforced concrete, the dimensions and rein-

forcement are shown in Figs. 13, 14 and 15. The stairway hangs free and leads to the top which is a walk; this was in service during the Exposition.

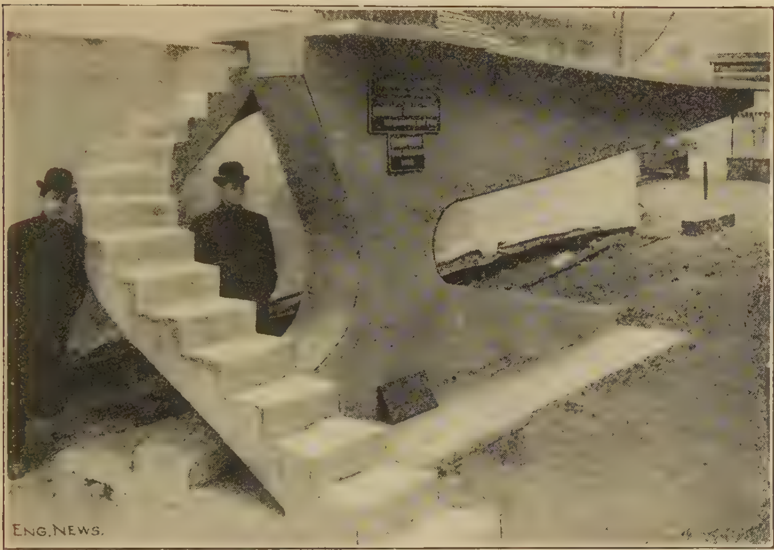


FIG. 12.—View of Reinforced Concrete Cantilever Tested to Destruction.

The cantilever was built, as was discovered afterwards, over a wooden box drain and the settlement of the foundation caused the cantilever to tilt towards the outer end.

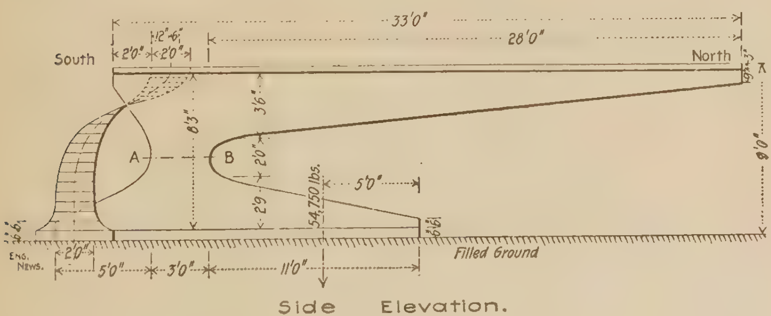
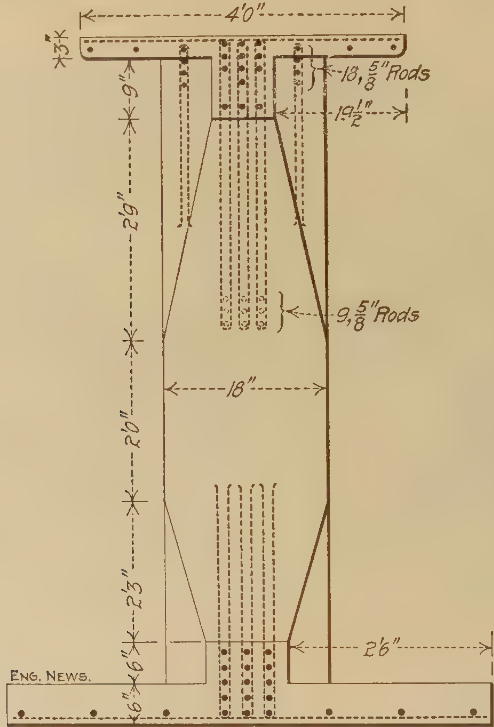


FIG. 13.

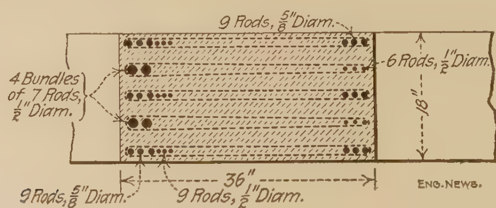
The forms, instead of being removed gradually, were quickly removed, and the sudden application of the load caused a strain



End Elevation, North.

FIG. 14.

which cracked the cantilever at the shank on the left-hand side. The props were restored and the cantilever washed with neat



Section A-B.

FIG. 15.

cement. The props were then gradually removed and the cantilever remained unchanged until tested with pig iron. The application of this load caused the cracks to open at left side of shank and the cantilever collapsed. As bars of the requisite size were not available a bundle of smaller rods was substituted; the shear members were insufficient to hold the cantilever and it pulled

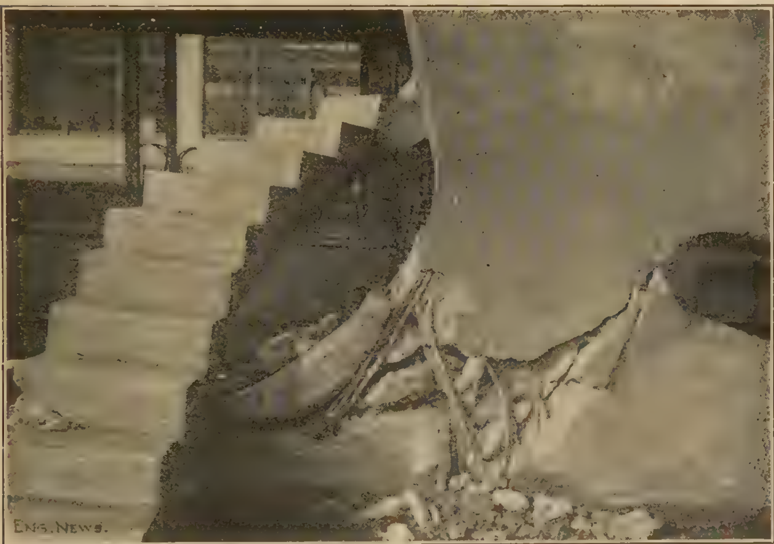


FIG. 16.—View Showing Failure of Reinforced Concrete Cantilever.

apart at the left shank and failed as shown in Fig. 16 before the compressive resistance of the concrete in the right center section of the shank had been reached. The loading was as follows:

Loads. lbs.	Deflection. in.	Remarks.
3060	1-16	
9845	1-4	
13735	11-32	
14760		Hair crack appeared.
17680	1-8	Opening at center 11-16 in. at outer end.
20607		Failed 4–11-16 in. extension at the center.

Besides these, tests were made of cement shingles, concrete sewer pipes, cement bricks and hollow blocks.

The Collective Portland Cement Exhibit and Model Testing Laboratory was assembled with a view of exploiting the American Portland Cement Industry and not with a view of advertising any particular process, plant or product. It was highly beneficial in disseminating a better knowledge of the proper methods of testing and of the nature, uses and properties of Portland cement; and in recognition of this fact it received a grand prize, the highest award of the Exposition.

It is to be regretted that the time available for the experimental work was not longer, so that much more data could have been obtained.

It is, however, a matter of gratification to all those connected with this exhibit that the work thus started will be continued under the direction of the United States Government and other interested persons, and it is to be hoped that the exhaustive series of investigations of structural materials which have been planned under the direction of the advisory board may be successfully carried out thereby supplying information of inestimable value to the engineering profession.

PROPER METHODS IN CONDUCTING PAINTING TESTS.

By Gustave W. Thompson.

A number of years ago, the President of our Society, Dr. Dudley, wrote a series of papers treating of the characteristics of paint and, we believe, for the first time in the history of the art, attempting some scientific understanding of paint problems. Not merely were these papers the first, in our opinion, that treated of the subject of paints scientifically, but, it may be said, since that time practically no progress has been made along this line. It is to be deeply regretted that Dr. Dudley has not had time to enlighten the public further in this direction; for, we are confident, had he been able to do so, the science of painting and paint manufacture would have been very much simplified. The situation, as it is presented to-day, is this: New paint materials are offered to the consumer, from time to time, these paint materials having more or less value, but in regard to which the manufacturers, as a rule, claim a somewhat more universal merit than these paints in actual use would warrant. It is natural for the paint manufacturer to advocate the use of his product or products for every condition under the sun, because he hopes by this broad advocacy to increase their sale. If there is one principle, however, on which the members of this society are pretty well agreed, it is that there is no complete paint which is suitable for all conditions of exposure; that is, every paint must, at least, have its various components put together in different proportions according to the conditions of exposure to which it is to be subjected.

We believe that it is the business of the engineer to design the paint which he is going to use under any given conditions. We believe that the paint manufacturers are only too anxious to supply what the engineer may demand. If the engineer starts out to select a paint, his proper attitude is not to take any one of the prepared paints on the market and specify that, because the manufacturer tells him it is the best for the purpose in question; but

it is his duty to make such experiments as are practical for the purpose of finding out what paint is best for the conditions to which the paint surface is to be exposed. To examine a paint on a large scale is, of course, the most satisfactory way, provided the paint turns out well. We are unquestionably of the opinion that the surest proof of a paint is its use, just as we are confident that the best way to detect a poison is to take it internally. The unfortunate part of the matter is, however, that the use of paint in order to find its value may leave the user firmly convinced that this value is a negative quantity. Supposing that he is able to try a paint in a limited way on full-sized structures, and the result, while not a minus result, is really very near that—that is to say, suppose the result leaves him somewhat in doubt—how is he going to tell whether the fault lay in the paint or its method of application? how can he be sure that the relative failure of the paint may not have been due to inherent destructive conditions external to the paint itself but peculiar to the structure painted? A painting test of this kind, properly called a "field test," is of inestimable value when accompanied by tests conducted under conditions all of which are known. These are what may be called "laboratory tests" and, if conducted with care and parallel to field tests, they act as a check upon the results obtained by these field tests and give a better basis on which to rest scientific conclusions. These laboratory painting tests, made with the intent to exposure under service conditions, should be supplemented by other laboratory tests which should parallel information enabling the engineer or paint chemist to determine the relative value of a given paint in advance of the results which are obtained by field or laboratory tests under service conditions. We must not reverse this order, however, and attempt to substitute purely chemical tests for exposure tests under service conditions until the laboratory tests have demonstrated their value.

By the term "painting tests" in our title, we have intended to include those tests which can be conducted with scientific accuracy, but which, at the same time, are as close as possible to ordinary practice so long as this accuracy is not impaired. Unfortunately, tests supposedly of this kind are in most cases without value: So much is this the case that laboratory painting tests are often spoken of in words of derision, as though they could be made

to produce any result desired by the skillful manipulator of the brush. In most cases, these painting tests are made by persons interested in exploiting certain products, whereas they should be conducted principally by the consumer. The primary cause for the lack of value which these painting tests usually show is that they are not conducted with sufficient accuracy. Tests of this kind should be conducted under the supervision of a competent engineer or chemist and with as much care as if a chemical analysis were being made.

Committee E has outlined a method of conducting painting tests for protective coatings, this method demanding proper attention to all those details which are essential to the obtainment of accurate results. These tests, when carried out by the sub-committee having them in charge, should prove of inestimable value. There are other paints, however, which, though "protective," are used for the purpose of producing a desired finish of appearance. Most paints are of this kind, and I propose, with your permission, to say a few words about painting tests made, using this class of paints:

Let us, to start with, take the question of the relative "covering power" of paints. To my mind, the term "covering power" has only one proper meaning; that is, the power to hide the surface painted. It is, as Dr. Dudley has pointed out, a function, first, of the light-destroying or absorbing power of the constituents of a paint and, second, of the difference in refractive index between the pigment and vehicle. Whatever it may be caused by, however, we are more interested in the actual facts of the case than in the reasons therefor. In comparing two paints for covering power, it is generally understood that these two paints should have practically the same color and be very nearly alike in tone, for the eye is not able to note accurately the difference in covering which exists between paints of different colors or tones. When we compare two paints of the same color and tone for covering power, our work is somewhat simplified when it is borne in mind that very few paints are homogeneous as regards pigment. Most paints contain several pigments, the principal one being a white pigment of some kind. Only with straight white or dark colors is the pigment likely to be homogeneous. Furthermore, with the colored paints consisting largely of white pigment, the tinting material is

so fine that only a very small amount is usually needed to give the tint desired. In this case the actual covering power of the paint is principally dependent upon the white pigment present. Our greatest interest, therefore, centers around the covering power of white paints; for, when we wish to design a paint of a certain color, we usually select a given white paint and add to it such coloring materials as have the highest possible tinting power and of which, consequently, we have to add the least amount possible. The result is that, practically speaking, tests for covering power are demanded for white paints only, and it is of these that I desire to speak.

On the threshold of our inquiry, we are confronted by two difficulties: The first of these has to do with the amount of vehicle we are to use to get the "consistency proper for painting." In the present state of the art, there is apparently no method for determining this consistency; the consistency proper for painting is simply a matter of rule of thumb. There is nothing standard about this consistency; it may be one thing in winter, another in summer; one thing with a flat brush, another with a round brush, and still another with the squirt gun. We have a refuge however, and that, it seems to me, is the only safe one. When we have mixed our paint to a "consistency proper," in our opinion, "for painting," let us record the formula on which we prepared the paint and let our report state this formula in full detail. If the paint was a prepared or ready-mixed paint, then the analysis of the paint should also be reported in as nearly formula form as possible. In other words, we may have difficulty in determining what is the consistency proper for painting, but we need have no difficulty in recording the composition of the mixture which was used in making a given test for covering power; and this, in the present state of the art, is all that we can ask. The second difficulty which presents itself is in the adoption of a spreading rate per gallon of paint. There can in practice, of course, be no standard spreading rate; and yet we have found that any white paint which has, according to our experience, a consistency proper for painting can be readily brushed out so as to cover 1,200 square feet to the gallon of paint when applied to a fairly smooth surface; and, in most cases, if it is not spread out at that rate the paint will run. We solve this difficulty of the spreading rate at which the

paint is to be applied in the same way that we solve the difficulty in connection with the consistency proper for painting; that is, we simply make the spreading rate followed a matter of record. To illustrate, let us suppose that we have received two paints which we desire to compare for covering power; these paints, we will say, are prepared paints—that is, they have been thinned to a "consistency proper," in the manufacturer's opinion, "for general painting." We would, first of all, analyse these paints to determine the formulæ on which they were prepared. Inasmuch as the pigments in the two paints may vary in composition and, consequently, in specific gravity we make a determination of the weight per gallon of paint as received; and, knowing the percentage by weight of the vehicle present, we calculate the percentages by volume of vehicle and pigment present, which gives us a somewhat better conception as to the nature of the paints. All the information we have thus obtained is recorded. Our next step would be to compare these two paints as to the relative ease with which they can be spread over the same area, without any particular regard to their covering power. If we find that they can be spread over the same amount of surface without, as is usual, great difficulty, we adopt a standard spreading rate for the two paints—say, 1,200 square feet to the gallon, one coat—and apply the paints to standard prepared surfaces at that rate; and when we are through we compare the paints for their covering power, or power to hide the surfaces painted. Now let us compare this method of making a painting test for the covering power of white paints with the method usually followed: Jones has a paint that he wants tested. He takes it to his friend Brown, the painter, and wants his opinion. Brown reports in a few days that the paint he received from Jones covered better than any paint he had ever used. Now, Brown may have been perfectly honest in making this report to Jones; but, unless the formula on which the paint was mixed and the rate at which it was spread is given, Brown's opinion is worse than useless.

We describe here more in detail our method of comparing white paints for covering power:

Use white pine boards, 30 inches long by 10 inches wide and, approximately, 1 inch thick. Each end of the board is provided with a cleat having a tongue fitting into a groove on the end of

the board and securely nailed on. The entire board, including the cleats, to be finished to the size given above. Three of these boards are primed with, we will say, the following paint mixture:

White lead paste....................	100 lbs.
Linseed oil, ⅓ boiled................	75 lbs.

No attempt is made to secure a definite amount of priming paint to the unit of surface; this, for the reason that the boards may vary considerably in their absorptive power. When this priming coat is dry, each board receives a diagonal stripe of lampblack in japan about 1 inch wide on one or both sides of the board, as may be desired. When this black stripe is dry it is given a second coat of paint mixed to a consistency proper for painting, the formula being recorded. The weight per gallon of the paint so mixed is then obtained by finding its specific gravity and multiplying by 8.33, which gives the weight per gallon. Inasmuch as the board which we are using has a total surface of 680 square inches, all we have to do is to find what the ratio is between 680 square inches and the spreading rate at which we desire to apply the paint in order to find the fraction of the gallon which we wish to apply to each board. If the rate adopted is 1,200 square feet to the gallon, then we get the formula:

680 sq. inches : 1,200 sq. feet :: 1..x

the reciprocal of "x" being the fraction of a gallon of paint to be applied to each board, one coat. Having the weight of the paint per gallon we easily get the amount of paint by weight to apply to each board, one coat on all sides. When this second coat of paint is thoroughly dry, a similar coat is applied; and, when dry, the boards can be compared for the covering power of the paints on them. We mention the painting of three boards with each paint to be compared. The purpose of this is that variation in results are obtained between boards which are apparently painted in an identical manner. These variations are not great, but it is thought best to eliminate them, to a certain extent, by painting three boards and selecting the one giving medium results for comparison with boards painted with other paints.

Tests conducted along these lines, we believe, will give valuable and scientific results, and will enable the intelligent person to draw safe conclusions.

Let me state here, by way of illustration of the usefulness of this method, one of the results obtained by tests comparing pure white lead and linseed oil with a mixture of white lead and a small amount of barytes with linseed oil. The pure white lead was mixed on the formula of 100 pounds of white lead paste to 30 pounds of linseed oil; two mixtures containing barytes were made on the same formula as the white lead and pure linseed oil, except that to the pure white lead was added an amount of barytes corresponding to 10 per cent. by volume of the white lead present and the amount of oil was also increased 10 per cent., so that the mixed paint contained in each case the same percentage of pigment by volume and the same amount of oil by volume. Another mixture was made, adding 20 per cent. by volume of barytes to the sample of white lead paint and a corresponding amount of oil. These three paints were then compared by the above method for covering power and spread at the uniform rate of 1,200 square feet to the gallon. The result was that both paints containing barytes showed a very perceptible diminution in covering power. Now, this illustration has not for its purpose the saying of anything in favor of white lead and against barytes, but simply to show that if the statement is made that a small percentage of barytes can be added to white lead without impairing its covering power, some explanation must be made as to the method by which such a result is obtained. If in any painter's hands the result has been found that the addition of a small percentage of barytes did not impair the covering power of the white lead, it must have been due either to the fact that less oil was used, or that less surface was covered per gallon of the paint containing barytes than by the straight white lead.

Perhaps the most important test that can be applied to paints is a durability test—that is a test as to the permanency of the paint film itself. Boards painted, as in the making of the covering power tests described above, can be exposed to the weather and the durability of the paint films observed. Durability tests, to be of value, should be conducted with the same care as the covering power tests. The formulæ on which the paints were mixed should be recorded, also the rate per gallon at which they were spread.

Quite recently, painting tests with a view to observing the durability of various paints were reported on to the International

Association of Master Painters and Decorators and the results obtained were published generally in the paint journals. Undoubtedly, these tests were conducted conscientiously and the conclusions reported give honest opinions about the results obtained. We feel, however, compelled to question these results for several reasons which appear to me to be very important. In the first place, single boards only were painted with each paint and exposed. At least three boards should have been painted and exposed alongside of each other, and the board which showed results about the average of the three should have been selected for comparison with other paints similarly selected. Very frequently, it will be found that two boards painted apparently in the same manner and with the same paint, will show differences in results due to differences in the boards themselves. In the second place, the formulæ on which the paints were mixed are not stated with sufficient detail. In the third place, there is no information given as to the spreading rate at which the respective paints were applied. Considering any two of the boards, the paint on one board may have been twice as thick as on the other, for all we know to the contrary. We have very little doubt that the thicker the paint film, the greater its durability. This emphasizes the importance of having painting tests conducted under the supervision of the engineer or chemist. The ordinary master painter is, we believe, thoroughly competent to interpret results and to conduct field tests on full-sized structures, but when it comes to preparing boards for exposure, special training is required, such as the chemist or engineer only can be said to have.

To conclude, no matter what the painting test may be, whether it be of colored paints or white paints, whether it be with homogeneous or mixed pigments, whether it be for covering power or durability, the essential features that we should insist upon are, that the formula of the paint should be stated fully; that the thickness of the film—or what is the same thing, the rate at which the paint is spread—should also be stated. These two requisites of proper painting tests should also be demanded in all tests for the permeability of paint films or their permanency, no matter how these tests may be applied. If we wish to compare two paint films for their permeability by the dextrine test, we should know, to start with, that these two films have approximately the same

thickness. It is a safe assumption that the thicker the paint film, the less its permeability. If we desire to compare two paint films for their permanency, we should know that these two paint films are of the same thickness, as the elasticity and general life of the film are proportionate to its power of resistance to oxidizing influences, and the thicker the film, the more permanent are its inner parts.

THE PRACTICABILITY OF ESTABLISHING STANDARD SPECIFICATIONS FOR PRESERVATIVE COATINGS FOR STEEL.

Topical Discussion.

Mr. Toch. Maximilian Toch.—It gratifies me very much to be invited to give my opinion on the Practicability of Establishing Standard Specifications for Preservative Coatings for Steel, but in treating this subject, I find it exceptionally difficult to know where to begin, and I should say, the subject is too vast a one to be taken up in a general way.

I call to mind the preservation of the steel in the supers ructure of our large buildings which must be treated in a certain way; again, the preservation of the grillage beams which form the founda tion of some of such structures. I have in view the requirements for the preservation of the structural steel in bridges against the action of the natural elements and against the action of electricity; again, the preservative coating for the interior of a structure in which a weak acid is evaporated continually at warm temperatures. These are merely suggestions of the various kinds of steel structures that have to be coated, some permanently and some temporarily, and I am sure you will agree with me that in each case a specific treatment is necessary.

A paint that will answer for the preservation of a hand-rail subjected to electrolytic action will manifestly not answer for steel that is to be immersed in water impregnated with benzol. For purposes of preservation, a coal car and a steel stack should not be treated in an identical manner, and similarly an elevated structure should be painted totally differently from the steel structure of a subway. A paint that may answer its purpose perfectly when subjected only to a variation in temperature of 40° F. and never subjected to brilliant light, may obviously fail when exposed to the sunlight and subjected to a variation of temperature of 130° F.

I am, therefore, of the opinion that each particular case requires appropriate treatment. I know of a building in which an acid-proof paint was necessary for the steel supports on the ground floor, and where a good linseed oil paint met all requirements on

the upper floors. It has also to be considered whether a beam be permanently imbedded in concrete or whether it can be looked after and maintained. A bridge which is partially subjected to fumes of locomotive gases must be treated differently from a bridge which crosses a stream and carries, perhaps, very light traffic. Pipes subjected to the action of brine cannot be treated in a manner similar to pipes which carry live steam. **Mr. Toch.**

I am quite sure that we have not sufficiently studied the action of electricity on paint and steel, and it is necessary for us before long to take this matter up very seriously.

As far as pigments are concerned, my personal opinion is that no single pigment is a panacea for all evils, but that a mixture of various pigments is frequently far superior.

Red lead if neutralized with a very light pigment like carbon black or graphite, makes a paint superior to either one or. he other alone. Certain forms of ferric oxide, those of high specific gravity and neutral conditions make most excellent structural paints for severe exposure, particularly when they are lightened in bulk with some other inert pigment. The ferric oxides have the great advantage of being unaffected by normal conditions. It frequently happens that red lead in the presence of sulphur vapor forms a lead sulphide, which, owing to its atomic increase, peels from the surface to which it is applied. It is not generally known but it is a fact that some of the ferric oxides are perfectly stable, are not affected by gases, and cannot change their composition; and that some of the pure red oxides of the composition Fe_2O_3 are used by rubber manufacturers for making red rubber, and when vulcanized in the presence of sulphur at a temperature of over 300° F., these oxides remain unchanged.

Much has been said in favor of hydro-carbon paints, and while I have a high opinion of these paints, I feel that an exact knowledge of the nature and conditions of the poly-methylenes is necessary before a uniformly successful paint can be made of these hydrocarbons. Sunlight is the great destroyer not only of poly-methylenes, but of many of the varnish and oil paints.

I made a series of tests extending over a year, which were very carefully carried out, and demonstrated to my own satisfaction that the asphaltum or pitches which were of the poly-methylene series give up hydrogen under the action of sunlight, thereby

Mr. Toch.

liberating the carbon. It is not my intention to go into this subject further than I have, for the reason that it is too scientific, but a fundamental study of the composition of raw materials of this nature is essential to the manufacture of hydro-carbon paints, because where alkaline and acid conditions prevail, it is necessary to use the poly-methylenes and the paraffines as bases. The pigment paints have serious disadvantages as primers against electrolysis.

Mr. de Wyrall.

MR. CYRIL DE WYRALL.—During the last three years I made a number of comparison tests under conditions differing from the ordinary, that is, in a place where we had everything we should not have had, and did not want, in the way of gases, condensation, humidity, etc. My remarks will be confined to actual tests, not laboratory tests, but service tests during the last three years, of preservative coatings for steel in the New York Rapid Transit Subway.

I should like to say a word in regard to the slow and quick-drying paints we have tried. Three of the best paints we tried dried free from dust in about ten minutes. The only three that have stood the different tests during that length of time are the paints that dried free from dust in ten minutes. You could lean against them without any danger in from thirty to forty minutes. The original specifications called for a coat of red lead and boiled linseed oil, weighing, ready-mixed, 22 lbs. per gallon. After the steel was erected it was properly cleaned and given another coat of red lead, and this was covered with a coat of white lead and boiled linseed oil. In about six cases out of ten, the columns had to be sand-blasted before they were erected. As soon as sand-blasted, coated and placed in position, after the work was finished, or as it progressed, we cleaned them thoroughly, getting off all the scale that might be left on, and coated them again with red lead and then with white lead. The materials used were chemically pure, each batch being tested, yet, notwithstanding all this, on Section 7 there were evidences of corrosion in eight months after the final coat was applied. It formed in little blisters like pin-heads all over the face of the columns. I watched them closely to see what would happen and little specks of rust came through at these points. You could wipe it off; the paint was perfectly good and there was no visible abrasion. These small spots,

came right together in a mass and started to spread out like water blisters. You could run a knife under them and find quite a mass of corrosion. At the time we started I took exception to the method of painting, that is, to the material that was being used. I said that under these conditions we needed something else besides linseed oil as a vehicle, for after saponification took place which would be the natural result where vegetable or animal oil was used, owing to the alkaline nature of the condensation, the coating would become porous, and most of the condensation would go right through it, leaving the surface of the paint intact and doing its deadly work underneath. Subsequent events proved this theory to be correct. We then made several tests, I think about one hundred, and finally we eliminated, for the above reason, any paint that contained linseed oil as a vehicle. Among the different coatings, we tried some that would not saponify. We now have three, and, of course, we are going to see which will last the longest. They have been on over two years and are yet in good condition. One proof of the difference in the efficiency of the coatings can be seen when a change in the outside atmosphere takes place. On the columns coated with leads and oil no condensation will appear for from 12 to 24 hours, while on the non-saponifying coating the moisture can be seen running down in 2 or 3 hours. The first absorbs the moisture until the coating is completely saturated, before showing on the surface, while the other being impermeable sheds it at once. I do not decry the value of laboratory tests, for I have found them extremely useful in many cases, but in this specific instance the value was nil, for the coatings that have out-lasted all the others in a comparative service test were condemned by the chemist of the Rapid Transit Commission. But as the conditions in our Subway are totally different from those in the laboratory, and as the coatings are good to-day, it is from them that we shall choose which to use in repainting. **Mr. de Wyrall.**

Our finish coating at stations is white enamel and to be effective as a preservative coating it should always be elastic. We had great difficulty in getting the two materials to combine, owing to the difference in the coefficients of expansion of enamels and paints. This has been overcome, and we now have an ideal finish for our stations. At first we also had some difficulty owing to the work being rushed, one coat following another far too

Mr. de Wyrall. quickly—sometimes on the same day—and the outer coats naturally cracked. But as we are now allowing ample time between successive coats for drying, the result is very satisfactory.

The conditions on the Subway are so different from any other, that a different material is required to meet them. While standard specifications will answer for a great many other products, in the case of preservative coatings, you can not expect one standard specification to fit all conditions.

I made an interesting experiment in the Subway the other day, regarding the effect of electrolysis. I had a coating brought to me which was said to be an insulator. I painted a section of the contact rail two coats and failed to get an arc through it, all though the rail is charged with 700 volts. If this coating wilstand a time-test we will be able to minimize the disintegration of steel caused by electrolysis to a great degree. I hope to report the result of this at our next meeting.

Mr. Evans. MR. S. M. EVANS.—Were the paints referred to as drying in ten minutes linseed-oil paints?

Mr. de Wyrall. MR. DE WYRALL.—No; these dried by evaporation.

Mr. Toch. MR. TOCH.—With reference to the Subway, permission was granted me to make an investigation as to the cause of the oxidation in the Subway, and, on the May 31, 1905, my report was published. It took a long time for me and my two assistants to establish the particular nature of the oxide found. In my report I note a great many analyses of the Subway rust, which is a peculiar one, and one we never found anywhere else. The composition is $Fe_2O_32H_2O + Fe_3O_4H_2O$—a very peculiar combination. We made over a hundred analyses to determine every possible condition, and I think the work was done very fairly, indeed. Strange to say, at the time I was doing this work I came here to Atlantic City for a few days' recreation, and in walking under the steel pier I noticed, at mean tide, the steel posts were badly rusted. I took off scales $\frac{1}{4}$ to $\frac{3}{8}$ in. thick and took them to my laboratory. I have a comparative table here showing that the Subway rust and that produced here are identical and not $Fe_2O_33H_2O$—the old formula for rust. The rust in the Subway was a yellowish brown streaked with black, just the same as the rust here on the steel pier. In making these comparative tests it was peculiar to find that when rust forms that way it sometimes skips a portion of the iron and forms another scale back of it.

PROTECTION OF IRON AND STEEL STRUCTURES

MEMORANDA OF ELEVEN YEARS' TESTS OF VARIOUS PAINTS.

By Louis H. Barker.

About eleven years ago experimental investigation was begun with numerous well-known and established iron paint-preservatives, in order to ascertain by actual exposure tests the best one to resist the destructive action on steel structures of sulphurous gases in the form of smoke combined with the moisture of steam, and since that time fifty or more paints and combinations have been tried. As will be seen by the accompanying table, the list included many kinds of asphaltum, rubber, graphite, carbon lead and iron paints, and though the results showed varying degrees of resistance, it is remarkable that even with three coats of paint not one was found that did not show rust in less than a year. Of course, it is to be understood that the exposures were made so as to subject the test bars to the severest action possible in order to obtain the quickest results.

In making the first series of tests new steel plates 10 inches square were used. As, however, the adverse conditions we were trying to overcome related to rusty steel, which is more difficult to preserve than new steel, rusty plates were substituted in all tests thereafter. And to still further endeavor to meet the existing conditions new plates were hung up and exposed to the smoke fumes until they became covered with sulphur scale, the thought being that an oxide scale due to atmospheric exposure might give different results. This scale or rust formation on these new plates apparently varied not only in amount, but also in the time of its formation, supposedly due to different chemical composition. As this might again give some variations in the experimental results, in order that all paints should be on as like footing as possible, angle bars 11 feet long were made use of and, as before, hung in the smoke until rusted, then cleaned with wire brushes, each foot of the bar painted with a different paint and again hung up. The results, however, continued to be unsatisfactory.

In examinations of the test bars from time to time it was seen

that upon many of them the paint was intact, but with protruding points which upon being pricked were found to be small rust formations pushing up the paint from behind, clearly indicating that it was not the failure of the paints but the rust action on the inner surface that caused the damage. As no rust can form without the presence of moisture, and as all paints are pervious to moisture (as Dr. Dudley's careful investigations of the subject have proved) this led to the conclusion that it would be necessary in some way to tightly seal the surface. Many kinds of materials for doing this were tried, with as many different results, until three years ago it was decided that a cheap paraffine paper answered the purpose best of all, and since that time all experimentation has been along that line. The few test bars that have been brought along and exhibited indicate the results. Besides the experimental bars referred to, the paper covering has been tried in a small practical way against smoke action, and after two years and three months exposure an examination of very recent date shows the outer paint, the paper and the first or adhesive coat all intact and, in many places where paper was removed for examination the adhesive coat not yet dry and the surface of steel the same as when painted.

With such satisfactory results from this paper-process in the smoke tests, it was concluded to make a large-scale application and severe test on a large number of eye beams supporting a floor over and within a few feet of salt water and upon which the rust was due not to smoke but to the almost continuous dampness and presence of sewer gases. This was done over a year ago, and up to this time indication of damage of no kind is apparent.

The mode of application of the paper is as follows: After the rust is carefully cleaned off by means of stiff wire brushes, a certain kind of tacky paint is applied, the paper then covered over and tightly pressed upon the painted surface, the joints of the paper slightly lapping. As soon as the paper is in place, it is ready for the outside coat of paint. It will be observed that by this process, the first coat of paint, the paper and the coat of paint over the paper can be applied with one scaffolding, thereby greatly reducing the cost, especially in high and dangerous places.

These experiments, extending over only three years, are of too short a duration to determine the value of paper as a protection for iron and steel, but they certainly bring out the fact, at least in

LIST OF PAINTS TESTED

Test No.	*a* No. 1.	*a* No. 2.	*a* No. 3.	*b* No. 4.	*c* No. 5.	*c* No. 6.	*c* No. 7.
Date of Exposure....	December, 1893.	February, 1895.	May, 1895.	January, 1896.	July, 1896.	July, 1897.	October, 1897.
Plate No. 1..	Red Lead.	Bessemer.	Ochre.	Red Oxide.	Red Lead.	P. & B. Universal.	Cerion.
" 2..	Red Lead.	Bessemer.	Ochre.	Red Lead.	Indurine.	P. & B. Rubberine.	Durable Meta[l] Coating.
" 3..	Graphite.	Rubberine.	Freight Car Brown.	Litho Carbon.	Dudley's Olive.	Lawrence Permanent.	Graphite.
" 4..	Graphite.	Rubberine.	Freight Car Brown.	Dudley's Olive.	Cerion.	Carbonizing Coating.	Sulphur and Acid Proof
" 5..	Eureka.	Black Anti-Rust.	Graphite.	Dudley's Freight Car.	Graphite.	Black Bridge.	English Red Oxide.
" 6..	Eureka.	Red Anti-Rust.	Red Lead.	Manganese.	Bessemer.	Mamolith.	Dudley's Asphaltum Lampblack.
" 7..	English Red Oxide.	Santarut.	Black Bridge.	American Iron & Steel Primer.	J. R. Smith.	Cerion.	National Red Lead and Re[d] Oxide.
" 8..	English Red Oxide.	Santarut.	Black Bridge.	Graphite.	Black Bridge.	Graphite.	Carbonizing Coating.
" 9..	....	Black Bridge.	Red Oxide.	Townsend's Asphalt Metallic.	Mamolith Brown.	B. P. S. Nobrac.	....
" 10..	....	Black Bridge.	Red Oxide.	Black Asphalt Metal.	Dudley's Freight Car.	Pure Rubber.	....
" 11..	....	Graphite.	....	Brown Asphalt	Red Oxide.	....	....
" 12..	....	Graphite.	....	....	Graphite.	....	....
13..	....	Red Oxide.	....	....	....	....	....
" 14..	....	Red Oxide.	....	....	....	....	....
" 15..	....	....	....	....	....	....	....
" 16..	....	....	....	....	....	....	....
" 17..	....	....	....	....	....	....	....
" 18..	....	....	....	....	....	....	....
" 19..	....	....	....	....	....	....	....
" 20..	....	....	....	....	....	....	....
" 21..	....	....	....	....	....	....	....
" 22..	....	....	....	....	....	....	....
" 23..	....	....	....	....	....	....	....
" 23..	....	....	....	....	....	....	....
" 24..	....	....	....	....	....	....	....
" 25..	....	....	....	....	....	....	....
" 26..	....	....	....	....	....	....	....
" 27..	....	....	....	....	....	....	....

a These tests were made on new plates, 10 inches square, painted three coats, one week between coats, and exposed when dry.

b This test was made on new plates, 10 inches square, painted two coats, one week between coats, and exposed when dry.

c These tests were made on old plates, 10 inches square, that had first been rusted by exposure to smoke, then removed, cleaned with wire brushes and painted two coats, one week between coats, and exposed when dry.

d This test was made on angle bars, 11 feet long, that had first been rusted by exposure to smoke, then

NOTE.—The order in which the different paints appear does not indicate their relative standing in

FROM 1893 TO 1904.

c No. 8.	c No. 9.	d No. 10.	e No. 11.		f No. 12.	
March, 1899.	December, 1900.	June, 1902.	March, 1904.		November, 1904.	
nti-Rust No. 1.	Red Oxide.	Black Cerion.	Paper	*Rubber.	Paper	†Red Oxide.
nti-Rust No. 2.	Red Oxide.	Rubber.	Paper	*Rubber.	Paper	†Red Oxide.
nti-Rust No. 3.	Red Oxide.	Toltz Asphalt.	Paper	*Rubber.	Paper	†Protectus.
ed Lead.	Cerion.	Pikrite Asphalt	Paper	*Rubber.	Paper	†Protectus.
altimore Varnish.	Cerion.	International Fire and Water Proof	Paper	*Non- 2 Corrosive.	Paper	†Rubber.
raphite.	Cerion.	Valentine's Helmoil.	Paper	†Non- 2 Corrosive.	Paper	†Rubber.
oltz Asphalt.	Anti-Rust No. 1.	American Acid Proofing.	Paper	*Non-Corrosive.	Paper	†Keystone.
ailey.	Anti-Rust No. 1.	Protectus Gray.	Paper	†Non-Corrosive.	Paper	†Keystone.
on-Corrosive Gray.	Anti-Rust No. 1.	Seaboard Carbolin.	Paper	*Rubber.	Paper	*Keystone.
arbonizing Coating.	Carbonizing Coating.	Standard Black Bridge.	Paper	*Rubber.	Paper	*Keystone.
ubber.	Carbonizing Coating.		Paper	*Rubber.		
urable Metal Coating.	Carbonizing Coating.	Paper.	Paper	*Rubber.		
erion.	Rubber.	....	Paper	*Protectus.		
ed Oxide	Rubber.	....	Paper	†Protectus.		
ireproof.	Rubber.	....	Paper	*Protectus.		
on-Corrosive.	Graphite.	....	Paper	†Protectus.		
....	Graphite.	....	Paper	*Toltz Asphalt.		
....	Graphite.	....	Paper	†Toltz Asphalt.		
....	Toltz Asphalt.	....	Paper	*Toltz Asphalt.		
....	Toltz Asphalt.	....	Paper	†Toltz Asphalt.		
....	Cold Japan.	....	Paper	*Non-Corrosive.		
....	....	....	Paper	†Non-Corrosive.		
....	....	....	Paper	*Non-Corrosive.		
....	....	....	Paper	†Non-Corrosive.		
....	....	....	Paper	*Red Lead. Onyx Structural.		
....	....	....	Paper	†Red Lead. Onyx Structural.		
....	....	....	Paper	*Tite Cote.		

d, cleaned with wire brushes and each 1 foot of bar painted with two coats of the different paints, one etween coats, and exposed when dry.

This test was made on bars 2 feet long, some of which were new, the remainder old as indicated, †New. Old bars had first been rusted by exposure to smoke, then removed and cleaned with wire brushes. Half bar covered with paper, the remaining half painted three coats, as above, one week between coats, and l when dry.

This test is now in progress, all bars but two being covered their entire length with paper. Only the coat of paint is given.

of the tests.

the case of smoke and gases, that the action begins from behind the paint and not from in front by the disintegration of the paint.

EXPERIMENTAL BARS EXPOSED EIGHT MONTHS—LOWER ONE-HALF PAPER, UPPER ONE-HALF PAINT, 3 COATS.

DISCUSSION.

The President. THE PRESIDENT.—I should like to call attention to one point in Mr. Barker's experiments from which I draw a great deal of comfort, namely, that if we may trust his experiments and the samples which he has exhibited to us, there can be little doubt that the point which has so often been brought out here is fairly well made, namely, if you can put on metal a coat which is impervious to moisture, you have got protection. I do not see how we can look at Mr. Barker's samples, and not be convinced that the key to the whole matter is in keeping moisture away from the metal, and unless our protective coating does this, it will be a failure.

There is another feature which is somewhat instructive, namely, how thick actually is a layer of paint. Using Mr. Thompson's figures and considering that there are 231 cubic inches in a gallon, and that this is spread over 172,800 sq. in., we find that the coat of paint is actually less than 0.002 in. thick. Of course, if we put on two or three coats, it would be two or three times this thickness, but on the other hand, quite a percentage of many paints as applied, is volatile matter, which passes off, so that even at the best, every protective coating is a very thin affair, and perhaps we are expecting too much from it.

I should like to remark also, on another point, namely, that the brush is an element in the problem. We recently had an experience which brings this out very well. We specified the mixing of the paint to be used in painting steel cars, and the car manufacturers said that the paint was unusable and could not be spread. On investigation we found that they were using practically whitewash brushes, and it is needless to say that we did not modify our specification; but simply asked that they use such a brush as a man with an ordinary wrist could use successfully. There is no doubt but that the brush is an element in painting.

Only one point further, namely, we have been puzzling a good deal of late as to whether it is possible to apply paint with a brush

and not leave air bubbles. Many practical painters say that it is not, and of course we are told that we must use more coats, in order to overcome this difficulty. It is needless to point out that the hope of success with successive coats is based on the supposition that two air bubbles will not come, one on top of the other. It is plain, I think, that we have a large field for study before use. The President.

WHAT IS THE BEST METHOD OF PAINTING STEEL CARS?

By Frank P. Cheesman.

The Committee appointed by the Master Car Builders' Association reported at their 1904 Convention as follows:

"Your Committee submits the following suggestions for

PAINTING OF STEEL CARS

"1. For New Cars: (*a*) The steel should be thoroughly cleaned of all rust and furnace scale before the car is assembled. (*b*) All joints before assembling should be thoroughly coated with coal tar. (*c*) After car is assembled all grease should be thoroughly removed from the steel and same given a good coat of carbon or graphite paint on the outside and underneath, and the inside a heavy coat of crude petroleum, coal tar applied hot, or some similar substance. (*d*) The outside to be given a second coat of graphite or carbon paint, as may be desired."

"2. For Old Cars: (*a*) All scale and rust should be removed wherever it appears on the car, by steel brushes or scrapers, and in the case of the inside of the car by any of the above methods or by the use of pneumatic hammers or mauls. (*b*) After all scale and rust have been removed the car should be thoroughly cleaned with steel scrapers or wire brushes and blown out with air, in order to present a clean surface for the paint. (*c*) The methods of painting recommended for new cars should be followed out in the case of old cars, after a clean surface is obtained."

The following report was made at the 1904 Convention of Master Car and Locomotive Painters by a committee especially appointed to draw up the best specifications for

PAINTING OF STEEL CARS.

"It is the sense of this Association that, in the construction and painting of steel cars, the following points are of vital importance to their preservation:

"*First.*—All flash or mill scale, rust, oil, grease and dirt should be entirely removed from all parts entering into the construction of cars before any paint is applied. We believe that this can be best accomplished by the use of the sand blast.

"*Second.*—During construction, all overlapping joints, wherever metal is placed upon metal, should be thoroughly coated with a heavy mixture of moisture repelling paint.

"*Third.*—The initial painting, being of the greatest importance, should be done in the best possible manner. The first coat should be applied immediately after metal has been sand-blasted and before the cleaned surface can accumulate rust.

"The material should be of an elastic nature and sufficient time should be allowed between coats for drying. It should be put on evenly in a workmanlike manner.

"*Fourth.*—We believe that not less than three coats should be applied to all exterior parts of body, including underframing, and two coats on the interior of body; also all parts of trucks except wheels and axles.

"*Fifth.*—We recommend a rigid inspection of the cleaning and painting of cars under construction by competent, practical men, believing this in the line of economy.

"*Sixth.*—We would suggest that the abuse of cars in service be stopped by discontinuing the loading of the hot slag, billets, etc. Also that the hammering of side sheets and other injurious methods used to facilitate unloading be discouraged.

"*Seventh.*—In the repainting of cars, all corrosion and loose paint should be removed with steel scrapers and wire brushes or the sand blast, and not less than two coats of an elastic preservative coating applied to all cleaned parts.

"As the greatest loss from corrosion is found on the interior parts of coal-carrying cars, we would consider the matter of painting those parts worthy of serious consideration."

We agree largely with the above reports and will consider the subject under two headings:

First, as applied to "New Cars Constructed by Steel Car Builders," and

Second, as applied to "The Repainting of Cars by Railroads."

Under the first heading, we desire to call attention to the fact that the conditions as we find them now, are such as make it impossible to secure a good job of painting, and it is simply money thrown away to attempt to furnish first-class material for the work as it is now done. In nearly all the large car shops it is the practice to put on two coats of paint in one day, followed usually by the stenciling of the cars that same day.

It is unnecessary to state that under these conditions neither adequate protection nor durable results may be expected, but until the present methods are changed we must meet them as they exist, and do the best possible under the circumstances. We believe that better results can be obtained by the application of only one coat rather than the forcing of the two coats to dry so that they can

be applied inside of twelve hours. We therefore suggest that in specifying paint for new steel cars, when not more than twelve to twenty-four hours are allowed for painting, that only a single coat be specified, and that care be taken to see that the surface to which this coat is applied is properly prepared by removing all rust, mill scale, grease and dirt by sand-blasting; that this work be donee under close inspection and that the paint be applied *immediately* after the sand-blasting as new rust will accumulate in a very short time.

For this one-coat work the pigment base of the paint should be pure blue lead, theoretically the vehicle ought to be only pure raw linseed oil, but as conditions make this impossible a pure selected turpentine drier should also be used. This drier should be of such a nature as to act both as a binder and a drier, and only enough should be used to dry in the required time which, for satisfactory results, should not be less than ten hours. All overlapping joints which cannot be reached to be repainted, should be coated with a heavy coat of blue lead made in semi-paste form. This shop coat should be followed in the course of six months with two coats of paint, at which time all rust should be removed by scraping and with wire brushes, and the abrasions repainted with blue lead. The main reason why we suggest blue lead in this connection, in preference to any other pigment for first coating, is that our experiments seem to prove conclusively that rust will not progress or extend under blue lead, hence it is only necessary to remove the rust that is visible, whereas in the use of any other paint pigment we find that the rust spreads under the paint for quite a considerable distance, and as it is covered and not visible it usually is not removed. Blue lead for single coat work stands weather exposure better than other pigments, and is not effected by sulphurous or carbonic acid gases which are very injurious to red lead.

Carbon black will not answer for single-coat work as it will not cover with as heavy a coating as is necessary to withstand abrasion, and it also takes too much drier when required to dry in such a short time, as say, ten hours. Graphite, when used for single-coat work, does not give durability, as under the condition of ordinary application it is made to cover too much surface, hence the coating is thin, and the pigment seemingly repels the vehicles, leaving many minute holes, causing corrosion.

We quote from a paper by Mr. H. M. Butts, Master Car Painter New York Central Railroad, read at a meeting of the Central Railroad Club, of Buffalo:

"We must admit that the combination of red lead and linseed oil properly used has served its purpose long and well, but experience has demonstrated that it has its faults, for it is not a success for finishing coats. Red lead, being too strong a pigment for the carrying vehicle the paint soon becomes hard and brittle and in time will chalk off. In this state it is pervious to moisture, which will soon penetrate to the metal and cause corrosion. Therefore, in order to obtain better and more lasting results, the red lead must be covered with a coating which carries a pigment fine enough to fill the pores of the oil, thus forming a more elastic and non-porous surface.

"If an elastic coating is preferable for finishing coats, why not for priming coats as well? This, I think, is coming to be understood as the better way, and hence red lead, which has stood in the front rank so long, is gradually being superseded by other pigments."

We, of course, would prefer to have the cars properly painted when built, but under the present limited trackage that exists in and around the car shops, it seems impossible to keep the cars for a long enough time to properly paint them. Again it frequently happens that the mill-scale cannot be removed properly at the time the cars are built, and until the mill-scale does separate from the steel, it is impossible to obtain a durable job of painting. Hence, if matters could be arranged so that at the end of say six months the car could be thoroughly overhauled and painted, a much more durable job would then be obtained.

As a rule the dryer used at the car shops is not of the quality that it should be, and while care is usually taken to see that the linseed oil is pure, the large amount of dryer added (in many cases as much as two gallons of dryer to one gallon of oil), destroys completely the life of the oil and makes the paint so brittle that in some instances it commences to peel within two weeks after it has been painted.

By applying only one coat we would be able to double the drying time, and consequently more than double the life of the paint, at a lower expense than by forcing on two coats in less than one-half the necessary time.

Under the second heading "The Repainting of Cars by Railroads," our first choice would be, after the surface is put in proper

condition by the removal of all rust and the retouching with blue lead of all bare spots, a coating of a paint made approximately of about 50 per cent. pure carbon black, 15 per cent. pure white lead,t 15 per cent. of pure white zinc and 20 per cent of selected inert pigment, non-hygroscopic in its nature, the vehicle consisting of pure linseed oil and selected dryers.

If the color of this paint is suitable, we would recommend the use of two coats of it. If, however, the road prefers to use its standard shade for a finishing coat, it should not be made up in the same manner for use on steel cars as when intended for wooden cars.

We also consider it of special importance both for the shop and the finishing coats that the size of the brush used should be specified in the original specifications, and a larger brush than a 6-0 round brush should not be allowed, and particular care should be taken to avoid the use of a flat, wide brush such as is now generally used for this work. In working with a wide, flat brush workmen cannot brush the parts in and on as well as it should be done.

The interior of the car should be painted when built, with one coat of the blue lead paint, and the bottom of the car should be protected with a heavy wooden floor, so arranged as to be readily removed when the car is repainted, at which time all the rust on the interior should be removed, and two coats of paint applied, the first of blue lead and the second of a paint made along the lines of the formula used by the Pennsylvania Railroad for their standard red freight car color.

The cars are usually not painted under cover, hence we have very variable results regarding durability. The sand-blasting and painting should be done under cover, especially in the case of the priming or foundation coat.

DISCUSSION.

Frank P. Cheesman.—With reference to the paper just read, for fear of being misunderstood we desire to state that we are not interested in any pigment or dry-color industry; hence we have no axe to grind, and can and do select from the entire field such pigments and vehicles as seem in our judgment best suited for this special work of painting steel cars. **Mr. Cheesman.**

We do not want to be understood as condemning generally the use of either red lead or graphite, as we are large consumers of both and they are both valuable paint pigments when used in the proper location, under suitable conditions and in correct combination with other selected pigments.

In suggesting blue lead for this work on steel cars, we are recommending a pigment which we do not manufacture ourselves, and one in which we have no commercial interest. It is a pigment which can be bought in the open market by any one.

Mr. G. W. Thompson.—As to the painting of steel cars, I cannot pretend to much knowledge. Mr. Cheesman has made some very interesting experiments and, in speaking in favor of certain pigments, evidently speaks from knowledge, and we are indebted to him. We have an inclination to inquire if blue lead, which is a sulphide compound, and a by-product in the smelting industry, affords protection in a paint, how is it that we attribute the oxidation of coal cars to the sulphur in the coal? If blue lead is protective, would it not be wise to use as a pigment something that would combine with the sulphur of the coal and so produce, in effect, blue lead in the paint? **Mr. Thompson.**

It seems to me that it is not just to characterize any pigment as generally good or bad unless we are clear that the faults which a given pigment may show are not due to some lack of care in the particular sample which we condemn. A pigment of a certain composition or name or class may be good or bad; it may be impalpably fine or coarse. I have heard it stated that certain

Mr. Thompson. work done in New York failed because a certain pigment was used. Such a statement, unless it is known that the best quality of pigment of the kind was used, is unjust. When a paint is condemned, all the information we can get should be afforded; then our judgment will be more reliable.

Mr. Evans. MR. S. M. EVANS.—The conclusion that the excessive use of dryer, often of a very inferior quality, is responsible in a large measure for the very unsatisfactory results obtained with paints designed for steel cars, seems to have been accepted by most of the authorities.

Now with respect to the dryer question, we are confronted with a commercial condition. It appears that at least a large percentage of the evil is the result of competitive bidding. In entirely too many cases success awards him who bids lowest. Now dryers used in this class of paints cost all the way from 15 to 50 cents a gallon; it is therefore usually very uncertain as to just what the nature of the dryer will be and where large proportions of the cheaper dryers are used, certainly all thought of any correspondence in the degree of elasticity between the paint film and the expansion and contraction of the iron and steel is lost sight of; hence the very general occurrence of brittle and cracking paints upon steel cars. So the point made by Mr. Cheesman seems to me very well taken, namely, that, if a single coat can be devised which would adequately protect a car for six months, it would be an accomplishment worth while.

In regard to blue lead, I feel some delicacy in speaking and shall be as brief as possible. In the first place I wish to state that I am interested in it, and I mention this fact that my remarks may be discounted by all. Blue lead is the result of volatilization of galena, or lead sulphide. It is really an imperfect volatilization for blue lead is a double combination of lead sulphate and lead sulphide, the lead sulphide being carried over in an unoxidized state. Mr. Thompson's point that the unoxidized portion of this pigment is possibly subject to oxidation is correct, and that this oxidation does take place is evident in the color of the material; but the unusually efficient protective qualities of this material when used in paint, leads to the conclusion that all of this oxidation takes place in the paint film, vaccinating it, as it were, against further oxidation which might affect the steel.

Of course, where hydrogen sulphide is to be contended against, no lead will stand that exposure. Perhaps the sulphates or sulphides will stand it longer than any other but any lead salt is bound to give in to that pressure. Blue lead resists sulphur dioxide gases fairly well. **Mr. Evans.**

But to return to the dryer, it seems to me on account of the fact that the dryers used in painting cars are of such a cheap quality, making the paint film brittle on the outside at the beginning and finally all through, that the net result after short exposure is for moisture to get to the steel; and I therefore heartily agree with Mr. Cheesman's main point, that it is highly advisable to devise some single coat calculated for a period of six months and then put on the balance under circumstances which will not make it necessary to put all of the coats on in a few hours.

The fact is that some paints are fit for some purposes and not fit for others. Few indeed are suitable for even general purposes. The functions of oils, dryers and pigments are capable of differentiation and it seems to me this Society, through its Committee E, on Preservative Coatings, could with great profit devote considerable time to the study and establishment of these functions.

THE PRESIDENT.—I should like to ask, Mr. Evans, is there any carbon in the blue lead? **The President.**

MR. EVANS.—Practically none. The carbon that occurs in blue lead is the resultant incident to the fuel used in volatilization. Formerly the proportion of carbon was larger than at present, the present process involving its elimination by combustion. The color of the blue lead is due almost entirely to the sulphide of lead in it. **Mr. Evans.**

MR. CYRIL DE WYRALL.—A word as to blue lead. I tried some blue lead on our elevated structure last November and in May we had to take it off again. Corrosion came right through it. **Mr. de Wyrall.**

MR. CHEESMAN.—I do not know how pure the lead was to which Mr. de Wyrall refers, or how it was mixed, but, as I mentioned before, a great deal depends on the dryer used. Blue lead we find a very hard pigment to grind and mix properly and very few have been able to do it successfully. It is impossible to mix it by hand and obtain durability. We worked at it for over five years before we got a drier that would give satisfactory results. **Mr. Cheesman.**

Mr. Toch. MR. MAXIMILIAN TOCH.—In reference to what Mr. Evans just said with relation to paint and the action of gases on blue lead, from my observation the question of dryer is simply to find one which will stop drying as soon as the paint is dry to the touch. In connection with this, the table oil-cloth trade, which has now assumed enormous proportions in the United States, has made most complete tests. Eighteen or nineteen years ago, when I first started, it was found that table oil-cloth did not last from one season to another. In taking up a piece of table oil-cloth it would crack in your hands which was found due to hastening its drying too much.

THE EFFECT OF ELECTRICITY ON PAINT.

By Joseph C. Blanch.

It is generally assumed that the conditions or rather influences under which iron rust is formed are well known, and doubtless sufficient knowledge of its progressive action has been acquired for the justification of the claim that when rust has attained a certain degree of development, its continued progress becomes a natural sequence, and that all known means for its arrest are unavailing, unless the affected places are perfectly freed from all traces of the oxide.

Instead of being a solid, coherent mass, rust or metallic oxide is loose and porous, absorbing and persistently retaining water, and in conjunction with the moisture of the atmosphere gradually developing and spreading until all of the iron has been converted into peroxide of iron or rust. But it has also to be considered that aside from chemical agents, such as acids, salts, water and gases, there is a certain contributory influence which has a direct connection with the rust-forming process and continues to extend the deleterious alteration or decomposition of the solid metal into a loose mass of peroxide of iron. This contributory influence is electricity. From many evidences that have come under our observation, we are led to believe that its influence as a rust-producing agency is very decided.

In order to give you a clearer insight into the influence of electricity upon the formation of rust and upon the alteration and possible premature destruction of iron and steel, together with their protective coverings or coatings of paint, I shall have to enter upon a more specific and analytical description of the details of what I consider a productive element of this special class of rust-forming agency. We have all, doubtless, seen at some time or other a bar of iron apparently solid and thoroughly protected against the action of the elements by being well painted, that upon closer examination was found to be so disintegrated or decomposed that its interior was entirely eaten up by rust, nothing but the exterior shell remaining intact. Such instances lead us irresistibly

to the conclusion that there must be some agency besides that of atmospheric action which causes metal, and iron and steel, in particular, to oxidize and decompose.

It is well-known that wherever any electrical or rather electro-chemical action is set up, there is always a decomposition or disintegration and a consequent deposition of molecules or atoms. Take, for instance, the chemical action produced in a pile or cell in which we call the liquid that is a conductor of electricity an electrolyte, and where the process by which the decomposition of the liquid is accompanied is designated electrolysis. An electrolytic decomposition, or electrolysis, occurs by reason of an electric current being generated solely by means of the decomposition of the liquid, which is in this instance decomposed into electro-positive and electro-negative atoms or ions which we call anions and kathions respectively. These anions and kathions have an irresistible impulse to migrate to the positive and negative stations set up in the cell. It is a similar migration established in a mass of metal that causes the decomposition, disintregation or decay of the said metallic body. Upon the decomposition taking place, however, there is, in accordance with the law of the conservation and correlation of physical force, another and counter electromotive force developed. The number of ions liberated by the aforesaid electrolytic action in a given time is always proportional to the strength of the current passing. The order of oxidizability and power to replace one another of the following substances is potassium, sodium, zinc, iron, hydrogen, lead, copper, silver, platinum, carbon, oxygen, black oxide of manganeses, peroxide of lead.

As a matter of fact the migration of the ions occurs wherever a liquid, two or more metals and an electrical current are found, and the ions liberated at the electrodes will be equal to the strength of the current multiplied by the electro-chemical equivalent of the ion. The chemical equivalent is proportional to the atomic weight divided by the valency (worth or value of a chemical atom as regards its power of replacing other atoms in chemical compounds). As we have said, the existence of a conducting liquid and an electrical current produces the decomposition or electrolysis, or in other words, the migration of ions or the molecules that appear at the anode and cathode. If there are metals in contact

with the liquid, those metals are deposited and come down in comminuted form from whatever elements they can be separated.

It will therefore be seen that in the electric railroad systems we have all that is necessary for the presence or appearance of the electrolytic decomposition and deposition, namely, liquid, currents and metals; and the continuous disastrous effects of the electrolytic decomposition and disintegration of metals that are employed in the various industries thus becomes a very serious question.

It may be said that iron is the most important of all metals, because of its many applications in the arts, especially in the modern construction of buildings, bridges, railroads, etc. In the New York subway we have iron, copper, lead, a very large electric current and plenty of water, thereby forming a complete and gigantic electrolytic cell. If an examination or measurement should be made it would be seen that the decomposition, deposition, etc., is always taking place and that the ions are in continuous motion.

Iron does not suffer any alteration in dry air or in dry oxygen at the ordinary temperature, but in damp air it soon undergoes an alteration and becomes covered with rust. This rust consists of an oxidation in its surface readily caused by the carbonic acid that is contained in small quantities in the atmosphere. The carbonic acid and oxygen changes the iron into carbonate or protoxide which absorbs a new portion of oxgyen and is transformed into hydrate of peroxide of iron. The carbonic acid liberated helps to produce the oxidation of a new quantity of metallic iron. As soon as rust commences in one place the oxidation extends very rapidly and, owing to the hygroscopic character of rust, when it once forms on iron the process will even continue in an atmosphere not saturated with water vapor.

The before named galvanic action or phenomena serves to accelerate the oxidation. The iron and the small sheet of oxide that has been produced on its surface form two elements of a pile or battery cell, in which the iron becomes positive and takes an affinity with the oxygen sufficient to decompose water at the ordinary temperature with a liberation of hydrogen gas.

The preservation of iron and steel and also of paints composed of metallic bases is a problem of very difficult solution, and demands a very serious study. In the first place the question arises, can

iron be protected against the above described chemical action? This may be possible because we know that iron is attacked by nitric acid, but if it is treated with or dropped into concentrated nitric acid it is no longer soluble in the acid but becomes passive. The same can be said of the different kinds of paint. For example, lead and peroxide of lead have different degrees of oxidation and therefore the mixture of paints requires the same care and judgment as does the selection of metals to produce electric batteries that will give a certain difference of potential. We have here a marked similarity between metals in electric batteries and paints on metals where humidity and electrical currents are adjuncts and are always present.

If we know the causes of disintegration where metallic contact is present the remedy can be found. The said remedy will be of some kind that will be able to destroy or eliminate one of the three causes of the electro-chemical action, namely:

1. Suppression of the electric current.
2. Suppression of the humidity.
3. Suppression of the conduction or migration of ions.

Let us consider now a particular typical case, namely, the durability of a coating on iron, steel, or copper in a place where electrolysis occurs. Is it possible to destroy or eliminate electrolysis? No. Is it possible to eliminate humidity or change the atmosphere? No. But it is possible to change the state or condition of the iron, and also to introduce an agent into the paint that will prevent or stop the electrolytic action by absorbing the oxygen or nullifying the migration of the ions. The fact that these things are possible is evidenced by the fact that iron that is soluble in dilute nitric acid becomes insoluble when immersed in concentrated nitric acid.

The development of the electrical industries increases the work of destruction by electrolytic action without any known means at present to stop the gradual disintegration occurring in all modern structures. Other electrical currents besides those produced by the electrical industries are active in this destructive work, as for example, telluric currents, electric waves, etc.

It has been my aim to lay stress upon the fact that in the endeavor to protect iron and steel structures, we must look beyond the mere effect of moisture upon metallic surfaces, and study the

galvanic action or phenomena which underlie and accelerate the oxidation of metallic substances, whether in large masses or in minute particles. In applying protective coatings or coverings to metal care must be exercised to employ such as are adapted not only to resist moisture, but also to prevent the setting up of any local electro-chemical action therewith. As soon as the electrolytic action that I have described can be stopped or prevented, we may confidently look for the increased durability of all structures in which iron and steel are employed.

Prof. L. v Tetmajer

LUDWIG VON TETMAJER.*

1850–1905.

Professor Ludwig von Tetmajer was born in Krompach, Hungary, July 14, 1850, and died in Vienna, Austria, January 31 1905. He married a daughter of the celebrated singer Mr. Kin-

*Memoir prepared by Professor Gaetano Lanza.

dermann, and he left two sons and one daughter, viz: Mr. A. H. von Tetmajer, diplom Architekt, Professor at the Staatsgewerbeschule in Pilsen, Mr. Bruno von Tetmajer, and Mrs. Elsa Breinl, wife of Mr. Breinl, diplom Ingenieur, Civil Engineer in Prague.

In 1868 he entered the Polytechnikum at Zurich, Switzerland, as a student, and completed his course of study in 1872. In 1872 he became Engineer of the Northeastern Railway of Switzerland. From 1873 to 1881 he occupied successively the positions of Assistant, of Privat Dozent, and of Honorary Professor of Engineering Sciences at the Polytechnikum at Zurich, being Ordinarius, i. e., regular Professor, from 1881 to October 1, 1901, when he accepted a call to be Rector and Professor of the Technische Hochschule at Vienna, Austria, which position he held at the time of his death.

He was President of the International Association for Testing Materials from 1895 until his death.

He was Honorary Member of each of the following societies, viz:

Schweizerische Ingenieur- und Architekten-Verein.

Schweizerische Ziegler-verein.

Verein Schweizerischen Cement-Kalk-und Gypspfabrikanten.

Professoren Congregation der Technischen Hochschule in San Paolo, Brazil.

He was also a member of each of the following societies, viz:

Swedish Academy of Sciences, Stockholm, Sweden.

Schweizerische Naturforschende Gesellschaft.

The following is a list of his publications, the greater part of this list being that recorded in Baumaterialienkunde of February 1, 1905:

1879. Die Inneren Kräfte an Statisch Bestimmten Trägern.

1880. Schmiedeiserne Dächer—Ein Beitrag zur Konstruktionslehre, als Manuscript autografirt.

1881. Zur Frage der Qualitätsbestimmung von Eisen und Stahl. Schweiz. Eisenbahn. Bd. XV, S. 16.

1881. Guhrdynamit und die Sprenggelatine beim Bahnbau am St. Gotthard, Schweiz. Eisenbahn. Bd. XIV, S. 68. (Auch in Broschüreform unter dem Titel: "Die Nobelschen Nitroglyzerin-Präparate." Zürich 1882.)

1881. Mitteilungen aus der Eidg. Anstalt zur Prüfung von Baumaterialien. Versuche mit Hanfseilen. Schweiz. Eisenbahn. Bd. XV, S. 24.

1881. Versuche mit Drahtseilen. Schweiz. Eisenbahn. Bd. XV, S. 28 u. 35.

1881. Resultate der Qualitätsbestimmungen von Metallen. Schweiz. Eisenbahn. Bd. XV, S. 64 u. 83.

1881. Zur Frage der Qualitätsbestimmung von Eisen und Stahl, Klassifikation dieser Materialien .Schweiz. Eisenbahn. Bd. XV, S. 92.

1882. Zur Frage der Qualitätsbestimmung Zäher Konstruktions-materialien. Resultate der Prüfung der Schweizerischen Kanonenbronze; Einfluss des Uchatius'schen Walzverfahrens Schweiz. Eisenbahn. Bd. XVI, S. 120.

1882. Mitteilungen aus der Eidg. Anstalt zur Prüfung von Baumaterialien. Resultate der Prüfung von Metallen (Stahlschienen). Schweiz. Eisenbahn. Bd. XVI, S. 120.

1883. Zur Frage der Qualitätsbestimmung Zäher Konstruktions-materialien. Schweiz. Eisenbahn. Bd. I, S. 35.

1883. Ueber den Erhärtungsvorgang Hydraulischer Bindemittel. Schweiz. Bauzeitung. Bd. I, S. 53.

1883. Einheitliche Nomenklatur und Klassifikation von Bau- und Konstruktionsmaterialien. I. Teil: Eisen und Stahl. II. Teil: Hydraulische Bindemittel. Herausgegeben vom Schweizerischen Ingenieur- und Architektenverein (1883).

1883. Zur Frage der Prüfung und Klassifikation Hydraulischer Bindemittel. Schweiz. Bauzeitung. Bd. I, S. 123.

1883. Normen für die Einheitliche Lieferung und Prüfung Hydraulischer Bindemittel. Herausgegeben vom Schweizerischen Ingenieur- und Architektenverein, 1883.

1883. Zur Frage der Knickungsfestigkeit der Bauhölzer. Schweiz. Bauzeitung. Bd. II, S. 141.

1883. Die Baumaterialien auf der Schweizerischen Landesausstellung, gemeinsam mit F. Locher, U. Meister und A. Koch. Zürich, Cæsar Schmidt, 1883.

1883. Der Portlandzementbeton auf der Schweizerischen Landesausstellung. Schweiz. Bauzeitung. Bd. II, S. 127.

1884. Der Kalk im Ziegeltone. Deutsche Ziegler- und Töpferzeitung. Jahrgang XV, S. 71.

1884. Uber die Wirkung Einiger Zumischmittel auf den Portlandzement. Schweiz. Bauzeitung. Bd. III, S. 143; Bd. VI, S. 38. Vergl. auch die Deutsche Tonindustrie-Zeitung.

1884. Zur Frage der Wirkung einiger Zumischmittel auf den Portland Zement. Deutsche Töpfer- und Zieglerzeitung. Bd. XV, S. 428.

1884. Offizielle Mitteilungen der Anstalt zur Prüfung von Baumaterialien am Schweizerischen Polytechnikum. I. Heft: Methoden und Resultate der Prüfung natürlicher und künstlicher Bausteine. II. Heft: Methoden und Resultate der Prüfung der Schweizerischen Bauhölzer.

1884. Zur Frage der Qualitätsbestimmung von Flussstahlscheinen. Schweiz. Bauzeitung. Bd. IV, S. 75.

1884. Der Wert des Dietzsch'schen Etagenofens fur die Schweizerische Zementindustrie. Broschüre, Zürcher und Furrer.

1885. Vorschlag zu einer Einheitlichen Nomenklatur Hydraulischer Bindemittel. Tonindustrie-Zeitung, Berlin.

1885. Bericht über die Relative Wertbestimmung Einiger Deutscher Normalprofile in Schweiss- und Flusseisen. Broschüre, Zürcher und Furrer, Zürich.

1886. Einfluss der Lochungsmethoden auf die Festigkeitsverhältnisse des Schmiedeisens. Schweiz. Bauzeitung. Bd. VII, S. 33.

1886. Offizielle Mitteilungen der Anstalt zur Prüfung von Baumaterialien am Schweizerischen Polytechnikum. III. Heft: Methoden und Resultate der Prüfung von Eisen und Stahl und Anderen Metallen.

1886. Der Schlackenzement. Schweiz. Bauzeitung. Bd. VII, S. 83.

1886. Ueber die Anforderungen an Eisenbahnschienen im Betriebe. Stahl und Eisen, 1886. S. 408.

1886. Die Sandwaschmaschine von Gressly—Ruge. Schweiz. Bauzeitung. Bd. VIII, S. 119.

1886. Zur Frage der Zuverlässigen Inanspruchnahme des Schmiedbaren Eisens. Schweiz. Bauzeitung. Bd. VIII, S. 141.

1887. Der Schlackenzement. Broschüre, Berlin. Verlag der Deutschen Ziegler- und Kalkbrennerzeitung.

1887. Zur Frage der Konservierung der Natürlichen Bausteine. Schweiz. Bauzeitung. Bd. IX, S. 91.

1887. Bericht über die Abänderungsvorschläge der Schweizerischen Normen fur die Einheitliche Lieferung und Prüfung Hydraulischer Bindemittel vom Jahre 1883. Broschüre, Zürcher und Furrer, Zürich.

1887. Uber die Volemenbeständigkeit Hydraulischer Bindemittel. Schweiz. Bauzeitung. Bd. X, S. 59–64.

1887. Zur Theorie der Knickfestigkeit. Schweiz. Bauzeitung. Bd. X, S. 93.

1887. Beschlüsse der Konferenzen zu München und Dresden über Einheitliche Untersuchungsnethoden; gemeinsam mit S. Bauschinger, Fr. Berger, C. Ebermayer, und Dr. Hartig, München bei Achermann.

1888. Die Knickfestigkeit der Bauhölzer. Schweiz. Bauzeitung. Bd. XI, S. 110.

1889. Die Angewandte Elastizitäts und Festigkeitslehre. Zürich, Verlag von Zürcher und Furrer.

1889. Der Schweizerische Normaldruckapparat für Zementproben. Schweiz. Bauzeitung. Bd. XIII, S. 7.

1889. Notiz zur Frage der Knickfestigkeit des Schmiedbaren Konstruktionseisens. Schweiz. Bauzeitung. Bd. XIII, S. 16.

1889. Denkschrift über die Errichtung einer eidg. Anstalt zur Prüfung von Baumaterialien. Bern (bei Körber).

1889. Lufttreibende Portlandzemente und die Darrprobe. Schweiz. Bauzeitung. Bd. XIV, No. I (als Beilage).

1889. Bericht über die Aufsuchung Entsprechend Abgekürzter Methoden zur Ermittlung der Volumbeständigkeit des Portlandzementes und der übrigen Hydraulischen Bindemittel. Zürich, Zürcher und Furrer, 1889.

1890. Das Basische Konvertereisen als Baumaterial. Schweiz. Bauzeitung. Bd. XVI, S. 111 u. 117.

1890. Bericht über die Untersuchung der Qualitäts- und Festigkeitsverhältnisse der Erzeugnisse der Eisenwerke der Herren de Wendel & Comp. Zürich, F. Lohbauer, 1890.

1890. Methoden und Resultate der Prüfung der Festigkeitsverhältnisse des Eisens und Anderer Metalle. IV. Heft der Offiziellen Mitteilungen. Zürich, F. Lohbauer, 1890.

1891. Ueber Neuerungen auf dem Gebiete der Gütebestimmung des Schmiedbaren Eisens. Schweiz. Bauzeitung. Bd. XVII, No. 19–20.

1892. Ein Beitrag zur Flusseisenfrage. Schweiz. Bauzeitung. Bd. XIX, No. 19, 20, 21, 22, u. 23.

1893. Die Knickfestigkeit der Mittleren Streben und der Gütewert des Materials der Mönchensteiner Brücke. Schweiz. Bauzeitung. Bd. XXI, No. 16 u. 17.

1893. Bericht über den Neubau, die Einrichtung und die Betriebsverhältnisse des Schweizerischen Festigkeitsinstitutes. V. Heft der offiziellen Mitteilungen. Zürich, F. Lohbauer, 1893. Vergl. auch Schweiz. Bauzeitung. Bd. XXII, S. 24.

1893. Das Thomaseisen als Nietmaterial. Schweiz. Bauzeitung. Bd. XXII, S. 17.

1893. Formeln zur Berechnung auf Knickung beanspruchter Stähe in Schweiss- und Flusseisen. Schweiz. Bauzeitung. Bd. XXII, S. 54.

1893. Zur Frage des Einflusses der Temperatur auf die Abbindeverhältnisse Hydraulischer Bindemittel. Deutsche Thonindustriezeitung. Bd. XVII, S. 187.

1893. Bericht über das Verhalten der Thomas-Stahlschienen auf den Schweizerischen Eisenhahnen. Zürich, Druck bei F. Lohbauer.

1893. Prof. Bauschinger. Schweiz. Bauzeitung. Bd. XXII, S. 147.

1893. Methoden und Resultate der Prüfung Hydraulischer Bindemittel. VI. Heft der Offiziellen Mitteilungen. Zürich, Druck bei F. Lohbauer.

1894. Ueber Betongewölbe Zwischen I—Trägern. Schweiz. Bauzeitung. Bd. XXIV, S. 4.

1894. Ueber dic Beschleunigten Volumenbeständigkeitsproken mit Hydraulischem Kalk und Roman-Zement. Schweiz. Bauzeitung. Bd. XXIV, S. 12.

1894. Ueber Mauer- und Zementarbeiten bei niedrigen Temperaturen. Schweiz. Bauzeitung. Bd. XXIV, S. 136.

1894. Resultate Spezieller Untersuchungen auf dem Gebiete Hydraulischer Bindemittel. VII. Heft der offiziellen Mitteilungen. Zürich, Druck bei F. Lohbauer.

1894. Ueber das Verhalten der Thomasstahlschienen im Betriebe. Verlag von Speidel, Zürich.

1895. Teilweise Umarbeitung des 23. Heftes der Bauschingerschen Mitteilungen über die Verhandlungen der Wiener Konferenz (1892). Verlag von Ackermann, München.

1895. Berichte der Unterkommission No. 2 der IV. ständigen Kommission für die Vereinbarung einheitlicher Prüfungsmethoden der Anstrichmassen als Rostchutzmittel.

1895. Beitrag zur Aufgabe 3: "Würdigung des Zusammenhanges Zwischen der Chemischen Zusammensetzung der Natürlichen Bausteine und deren Wetterbeständigkeit."

1895. Beitrag zur Aufgabe 4: "Methoden der Unterschung der Qualität insbesondere der Wetterbeständigkeit der Dachschiefer."

1895. Beitrag zur Aufgabe 19: Ueber die Unzuverlässigkeitserscheinungen des Flusseisens.

1895. Bericht über die Tätigkeit des Vorstandes der IV. Ständigen Kommission, etc., an dem Internationalen Kongress. Zürich im September, 1895.

1896. Die Gesetze der Knickfestigkeit der Technisch Wichtigsten Baustoffe. VII. Heft der Offiziellen Mitteilungen Zürich, Druck bei F. Lohbauer.

1896. dto. dto. Auszug aus dem VIII. Hefte der Offiziellen Mitteilungen. Schweiz. Bauzeitung. Bd. XXVIII, S. 68.

1896. Methoden und Resultate der Schweizerischen Bauhölzer; Ausstellungsausgabe vom Jahr 1896. Zürich, Druck bei F. Lobhauer.

1896. Metamorphosen der Schienenstahlbereitung und des Prüfungsverfahrens von Stahlschienen. Shweiz. Bauzeitung. Bd. XXVIII, S. 130 u. f.

1896. Mr. M. H. Le Chatelier: "Ueber Volumbeständigkeitsversuche des Herren Prof. L. v. Tetmajer." Paris, Le Ciment. Bd. I, No. 8.

1896. Bericht über den Neubau, die Einrichtung und die Betriebsverhältnisse der Schweizerischen Materialprüfungsanstalt. V. Heft der Offiziellen Mitteilungen, 2. Auflage. Zürich, Druck von F. Lohbauer.

1896. Offiziellen Mitteilungen der Anstalt zur Prüfung von Baumaterialien am Schweizerischen Polytechnikum: II. Heft, 2. Auflage: Methoden und Resultate der Prüfung der Schweizerischen Bauhölzer.

1897. VII. Heft, 2. Auflage: Resultate Spezieller Untersuchungen auf dem Gebiete Hydraulischer Bindemittel. Zürich, Druck bei F. Lohbauer.

1898. I. Heft, 2. Auflage: Methoden und Resultate der Prüfung Natürlicher und Künstlicher Bausteine.

1900. I. Heft, 3. Auflage: Methoden und Resultate der Prüfung Natürlicher und Künstlicher Bausteine.

1900. IX. Heft: Methoden und Resultate der Untersuchungen des Aluminiums und Seiner Abkömmlinge. Zürich, Druck bei F. Lohbauer.

1901. VII. Heft, 2. Auflage: Die Gesetze der Knickungs- und der Zusammengesetzten Druckfestigkeit der Technisch Wichtigsten Baustoffe. Zürich, Druck bei A. Martwalder.

1901. Normen für eine Einheitliche Benennung, Klassifikation und Prüfung der Hydraulischen Bindemittel. In Kommission bei E. Speidel, Zürich.

1897. Bericht über die Tätigkeit des Vorstandes des Internationalen Verbandes für die Materialprüfung der Technik vom Züricher bis zum Stockholmer Kongress.

1901. dto. dto. vom Stockholmer bis zum Budapester Kongress. Uber Neuerungen auf dem Gebiete der Trockeneinrichtungen für Rohmehlziegel der Zement-Industrie.

1903. Die Gesetze der Knickungs, und der Zusammengesetzten Druckfestigkeit der Technish Wichtigsten Baustoffe Leipsig.

1903. Méthodes d'Essais, et Résultats des Recherches sur les Propiétés de Resistances du fer et d'autres Métaux, traduit de E. Meister. Zürich.

1904. Die Angewandte Elastizitäts und Festigkeitslehre. Leipzig.

That Professor von Tetmajer was one of the most prominent investigators in engineering subjects, especially in those connected with the strength, and other properties of the materials of construction, is evident from the list of his publications. While the greater part of his work of investigation was performed at Zurich, the results exerted a great influence and gave a stimulus to work of this character throughout the world. Moreover, his valuable services were not confined to experimental investigation, but were also of great value in theoretical lines.

Professor von Tetmajer was a very able, and much beloved teacher, and performed work of the greatest importance in executive capacities, especially in his organization of the Materialprüfungsanstalt at Zurich, and his subsequent reorganization of that at Vienna, and in his organization and conduct of the affairs of the International Association for Testing Materials. His magnificent services in the latter capacity appeal with special force to the members of the American Society for Testing Materials, inasmuch as this Society owes its origin to the parent International

Association, with which Professor von Tetmajer's life and work have been so closely identified.

In the death of Professor von Tetmajer theAmerican Society has lost an investigator of the highest class, a leader, and a friend; and the Engineering Profession has lost one whose whole life was devoted to the improvement, and advancement of its work, and one who has left us in the midst of his active life, and who, had he been spared to us longer, would have achieved even greater triumphs.

CHARTER

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

To the Honorable the Judges of the Court of Common Pleas No. 2 *in and for the City and County of Philadelphia: of March Term,* 1902, *No.* 2056:

In compliance with the requirements of an Act of the General Assembly of the Commonwealth of Pennsylvania, entitled "An Act to Provide for the Incorporation and Regulation of Certain Corporations," approved the 29th day of April, A.D. one thousand eight hundred and seventy-four, and the supplements thereto, the undersigned, Henry M. Howe, Charles B. Dudley, Edgar Marburg, Robert W. Lesley, Mansfield Merriman, Albert Ladd Colby and William R. Webster, six of whom are citizens of Pennsylvania, having associated themselves together for the purposes hereinafter set forth, and desiring that they may be incorporated according to law, do hereby certify:

1. The name of the proposed corporation is the "AMERICAN SOCIETY FOR TESTING MATERIALS."

2. The corporation is formed for the Promotion of Knowledge of the Materials of Engineering, and the Standardization of Specifications and the Methods of Testing.

3. The business of the said corporation is to be transacted in Philadelphia.

4. The said corporation is to exist perpetually.

5. The names and residences of the incorporators are as follows:

HENRY M. HOWE, 27 West Seventy-third Street, New York.
CHARLES B. DUDLEY, Altoona, Pa.
EDGAR MARBURG, 517 South Forty-first Street, Philadelphia.
ROBERT W. LESLEY, 22 South Fifteenth Street, Philadelphia.
MANSFIELD MERRIMAN, South Bethlehem, Pa.
ALBERT LADD COLBY, South Bethlehem, Pa.
WILLIAM R. WEBSTER, "The Bartram," Thirty-third and Chestnut Streets, Philadelphia.

6. The management of the said corporation shall be vested in an Executive Committee, consisting of six (6) members, viz.: the Chairman, the Vice-Chairman, the Secretary, the Treasurer and two other members of the corporation, and such other officers as the corporation may from time to time appoint.

7. The corporation has no capital stock, and the members thereof shall be composed of the subscribers and their associates and of such persons as may from time to time be admitted by vote in such manner and upon such requirements as may be prescribed by the By-Laws. The corporation shall nevertheless have power to exclude, expel or suspend members for just or legal cause, and in such legal manner as may be ordained and directed by the By-Laws.

8. The By-Laws of this corporation shall be admitted and taken to be its laws subordinate to the statute aforesaid; this Charter; Constitution and Laws of the Commonwealth of Pennsylvania, and the Constitution of the United States; they shall be altered and amended as provided for by the By-Laws themselves; and shall prescribe the powers and functions of the Executive Committee herein mentioned and those to be hereafter elected, the times and places of meetings of the Committee and this corporation; the number of members who shall constitute a quorum at the meetings of the corporation, and of the Committee; the qualifications and manner of electing members; the manner of electing officers; and the powers and duties of such officers; and all other concerns and internal arrangements of the said corporation.

Witness our hands and seals this twenty-first day of March, A.D. 1902.

(Signed)
EDGAR MARBURG,
R. W. LESLEY,
WM. R. WEBSTER,
MANSFIELD MERRIMAN,
ALBERT LADD COLBY.

BY-LAWS.

Article I.

MEMBERS.

Section 1. Any person, corporation or technical society can become a member of this Society upon being proposed by two members and being approved by the Executive Committee.

Sec. 2. Any member who subscribes annually the sum of fifty dollars ($50) towards the general funds of the Society shall be designated a contributing member, his rights and privileges as a member remaining unchanged. Contributing members shall be exempt from the regular membership dues.

Sec. 3. Applications for membership and resignation from membership must be transmitted in writing to the Secretary.

Article II.

OFFICERS AND THEIR ELECTION.

Section 1. The officers shall be a President, Vice-President, Secretary and Treasurer.

Sec. 2. The offices of Secretary and Treasurer shall be held by the same person.

Sec. 3. These officers shall be elected by letter-ballot, at the Annual Meeting, and shall hold office for two years.

Sec. 4. The Executive Committee shall consist of these officers and also the last past-President and three members, two being elected by letter-ballot at each Annual Meeting in the odd years and one at each Annual Meeting in the even years.

Sec. 5. The President shall be, *ex officio*, the nominee for American Member of the Council of the International Association.

Sec. 6. The Secretary shall receive a salary to be fixed by the Executive Committee.

Sec. 7. The officers and members of the Executive Committee of this Society to hold office until the next election under these By-Laws, shall be as follows: To hold office for two years—President, Charles B. Dudley; Vice-President, R. W. Lesley; Secretary-Treasurer, Edgar Marburg; members of the Executive Committee, Henry M. Howe and James Christie. To hold office

for one year—members of the Executive Committee, Albert Ladd Colby and John McLeod.

Sec. 8. The above officers and members of the Executive Committee, as well as all succeeding officers and members of the Executive Committee elected under these By-Laws, shall serve for the respective terms to which they shall have been elected, or until their successors shall have been duly elected.

Sec. 9. The Executive Committee shall have the power to fill any vacancies occurring in their number by death, resignation or otherwise.

Sec. 10. The election of officers and members of the Executive Committee shall be by letter-ballot. The Executive Committee, before each Annual Meeting, shall appoint a Nominating Committee, whose duty it shall be to nominate a full list of officers. The list of nominations so made shall be submitted to the membership not more than eight (8) nor less than four (4) weeks before the coming Annual Meeting.

Further nominations, signed by at least ten (10) members, may be submitted to the Secretary in writing at least four (4) weeks before the Annual Meeting, and such nominations shall also be submitted to the membership on the official ballot.

Article III.

meetings.

Section 1. The Society shall meet annually. The time and place of each meeting shall be fixed by the Executive Committee.

Sec. 2. Special meetings may be called whenever the Executive Committee shall deem it necessary, or upon the request in writing to the President of twenty-five (25) members.

Article IV.

dues.

Section 1. The fiscal year shall commence on the first of January, and all dues shall be payable in advance.

Sec. 2. The annual dues of each member shall be \$5.00. Members holding membership also in the International Association for Testing Materials shall pay annually the additional sum of \$1.50, which shall be transmitted by the Secretary to the International Association.

Sec. 3. Any member of the Society whose dues shall remain unpaid for the period of one year shall forfeit the privileges of membership. If he neglects to pay his dues within thirty days thereafter, and after notification from the Secretary, his name may be stricken from the roll of membership by the Executive Committee.

Article V.

Amendments.

Section 1. Proposed amendments to these By-Laws, signed by at least three members, must be presented in writing to the Executive Committee at least four weeks before the next Annual Meeting. In the notices for this meeting the proposed amendments shall be printed. At the Annual Meeting the proposed amendment may be discussed and amended and may be passed to letter-ballot by a two-thirds vote of those present.

If two-thirds of the votes obtained by letter-ballot are in favor of the proposed amendment, it shall be adopted.

Sec. 2. The Executive Committee is authorized to number the Articles and Sections of the By-Laws to correspond with any changes that may be made.

RULES GOVERNING THE EXECUTIVE COMMITTEE.

1. Regular meetings shall be held on the first Saturday in January, April, July and October. Four members shall constitute a quorum.

At each meeting the Secretary shall report the names of all new members and of members who have resigned during the previous quarter, and shall present a financial statement.

At the January meeting the Secretary shall report the names of all members whose dues are unpaid.

The accounts of the Secretary shall be duly audited at the middle and close of each fiscal year, and the report of the auditors shall be presented in writing at the July and January meetings.

2. Special meetings may be held at any time at the call of the President, or upon the written request of four members of the Executive Committee. The notice for such meetings shall be mailed by the Secretary at least one week in advance of the meeting, and the business shall be stated in the notice.

3. The Secretary shall transmit to the International Association within five days after the first day of January, April, July and October $1.50 for each member whose dues were paid in the previous quarter together with the names of those members.

No other expenses shall be paid except on vouchers certified to be correct by the Chairman of the Committee on Finance, or a member thereof designated by the Chairman.

GENERAL INFORMATION.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

Historical.—The International Association for Testing Materials had its origin in a conference of a small group of workers in experimental engineering held in Munich in 1882, at the instance chiefly of the late John Bauschinger. Meetings on a larger scale were subsequently held in Dresden (1884), Berlin (1886), Munich (1888), Vienna (1893), and Zurich (1895). At the Zurich Congress the International Association for Testing Materials was formally organized, the Second Congress was held at Stockholm in 1897, the Third Congress met at Buda-Pesth in 1901,* and the Fourth Congress will assemble at St. Petersburg in 1906.

Membership.—According to the latest official report (November, 1904) the membership, exclusive of that in the United States, is distributed as follows: Russia, 392; Germany, 343; Austria, 176; France, 166; Hungary, 88; Switzerland, 76; Denmark, 50; Sweden, 50; Italy, 47; England, 46; Belgium, 44; Holland, 40; Norway, 37; Roumania, 18; Spain, 13; Portugal, 11; Australia, 4; Luxemburg, 4; Servia, 3; Brazil, 2; Argentine Republic, 1; Chili, 1; Japan, 1. Total, 1,613, representing 23 countries.

Objects.—The objects of the Association, as set forth in its By-Laws,† are: "The development and unification of standard methods of testing; the investigation of the technically important properties of the materials of construction and other materials of technical importance, and also the perfecting of apparatus used for that purpose."

The important subject of specifications has, however, also been included within the scope of the Association's activity. Thus, International Committee No. 1 has been charged to report on the following problem: "On the basis of existing specifications, to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds."

* The Third Congress, originally scheduled for 1900, to be held at Paris during the Exhibition, was abondoned in order not to conflict with the International Testing Congress, conducted under French auspices.

† These By-Laws are given in full on pp. 543–545.

Again, in pursuance of American initiative at the Buda-Pesth Congress (1901), Committee No. 1 has been enlarged by the addition of three American members, with a view of reporting on "Standard International Specifications for Cast Iron and Finished Castings," and Committee No. 22 has been instructed to report "On the Feasibility of the Establishment of Standard International Specifications for Cements."

Administration.—The affairs of the Association are administered by a Council, consisting of the President and one representative (member of Council) from each country having a membership of twenty (20) or more.

Methods.—The original plan was to conduct investigations almost exclusively through the agencies of international committees. These committees proved unwieldy, however, by reason of their large membership, with the added difficulties arising from geographical separation and differences of language. In pursuance of resolutions at the Buda-Pesth Congress (1901) the Council has discharged some of these committees, reassigning the problems in part to individual referees.* In the case of questions of direct international concern the original international committees are continued.

At the international congresses the reports of these committees as well as individual contributions by members are presented and discussed.

Publications.—On May 5, 1896, the International Council effected an arrangement with the publishers of *Baumaterialenkunde*† (Materials of Construction) by which that journal became the official organ of the Association. Since July, 1896, this journal has published the Proceedings of Congresses and other official matter in German and French. The fact that the Association did not furnish printed Proceedings to members free of charge, and that no provision had been made for translation into English, gave rise to no little dissatisfaction. At the Buda Pesth Congress (1901) the International Council was accordingly authorized to perfect a new arrangement by which all official matter is now published in three separate editions (German, English and French)

* For complete list of problems, committees and referees, see pp. 546–552.

† *Baumaterialenkunde:* Published bi-weekly at Stuttgart, Germany, in German and French. Regular subscription price $3.50 per annum; special terms to members of the International Association for Testing Materials, $2.50 per annum. Address: Staehle & Friedel, No. 57 Tuebinger Street, Stuttgart, Germany.

and sent free of charge to every member of the Association in whatever language is preferred.

ORGANIZATION OF THE AMERICAN MEMBERS OF THE INTERNATIONAL ASSOCIATION.

Historical.—With a view of bringing the members of like nationality into closer relations among themselves, and in order to simplify the management and render the work of the International Association more effective, it was decided at the Stockholm Congress (1897) to encourage the consolidation of the membership in the various countries into separate national organizations. In pursuance of this action the American members met in Philadelphia on June 16, 1898, and organized under the name of the "American Section of the International Association for Testing Materials."

In March, 1902, the Executive Committee of the American Section applied for a Charter under the laws of the State of Pennsylvania for purposes of incorporation under the proposed new name of the "American Society for Testing Materials." This Charter was duly granted, and at the Fifth Annual Meeting, held at Atlantic City, N. J., it was unanimously adopted on June 12, 1902.

At the Eighth Annual Meeting (1905) the By-Laws were amended with a view of leaving membership in the International Association to the individual option of the members of the American Society. This amendment was adopted by letter-ballot of the Society.

Objects.– The objects of the Society are essentially identical with those of the International Association, with which it stands in direct organic relation, both through its membership in the same as a body, and through the individual membership on the part of many of its members.

As stated in the Charter: "The corporation is formed for the promotion of knowledge of the materials of engineering, and the standardization of specifications and the methods of testing."

The standardization of specifications is considered one of the most important functions of the Society. The method of procedure is to submit proposed standard specifications prepared by the various committees for general discussion at the annual meetings of the Society. The specifications in their original or amended form are then referred, by majority vote, to letter-ballot of the

Society for adoption as Standard Specifications. A list of the Standard Specifications thus far adopted by the Society is subjoined under *Publications*.

Representation on the International Council.—The American members are entitled to one representative on the International Council. By the new Statutes of the Association (1901): "the members of Council shall be proposed by the members of each country; their final appointment being confirmed by the Congress." According to the By-Laws of the American Society the President becomes, "*ex officio*, the nominee for American Member of the Council of the International Association."

Meetings.—The Society meets annually at a time and place fixed by the Executive Committee. Special meetings may also be called in accordance wth the provisions of the By-Laws.

Annual meetings have been held in past years as follows:

First Annual Meeting, Philadelphia, Pa., House of Engineers' Club of Philadelphia, August 27, 1898.

Second Annual Meeting, Pittsburg, Pa., Rooms of Engineers' Society of Western Pennsylvania, August 15, 16, 1899.

Third Annual Meeting, New York, N. Y., House of American Society of Mechanical Engineers, October 25, 26, 27, 1900.

Fourth Annual Meeting, Niagara Falls, N. Y., International Hotel, June 29, 1901.

Fifth Annual Meeting, Atlantic City, N. J., Hotel Traymore, June 12, 13, 14, 1902.

Sixth Annual Meeting, Delaware Water Gap, Pa., Hotel Kittatinny, July 1, 2, 3, 1903.

Seventh Annual Meeting, Atlantic City, N. J., Hotel Traymore, June 16, 17, 18, 1904.

Eighth Annual Meeting, Atlantic City, N. J., Hotel Chalfonte, June 29–July 1, 1905.

Membership.—The number of American members at the time of the organization meeting in 1898 was 70. The membership reported at the successive annual meetings was as follows: (1899) 128, (1900) 160, (1901) 168, (1902) 175, (1903) 349, (1904) 485, (1905) 677, and it is now (November, 1905), 759.

Methods.—The operations of the Society are conducted in part under the auspices of the International Association and in part independently.

The number of American representatives on international committees is fixed by the International Council. These American sub-committees are authorized, however, to increase their number

at pleasure, subject always to the approval of the Executive Committee of the American Society. The sense of these enlarged subcommittees on all questions is determined by majority vote; but on the international committees the representation and the number of votes allowed remain as originally fixed by the International Council.

The American Society appoints other committees at its discretion entirely independently of the International Association. On committees concerned with subjects involving commercial interests, the policy is to accord equal numerical representation to engineers or scientists, and to manufacturers.

The Committees of the American Society are now as follows:

A. On Standard Specifications for Iron and Steel.

B. On Standard Specifications for Cast Iron and Finished Castings.

C. On Standard Specifications for Cement.

D. On Standard Specifications for Paving and Building Brick.

E. On Preservative Coatings for Iron and Steel.

F. On Heat Treatment of Iron and Steel.

G. On the Magnetic Properties of Iron and Steel.

H. On Standard Tests for Road Materials.

I. On Reinforced Concrete.

J. On Standard Specifications for Foundry Coke.

K. On Standard Methods of Testing.

L. On Standard Specifications and Tests for Clay and Cement Sewer Pipes.

M. On Standard Specifications for Staybolts.

N. On Standard Tests for Lubricants.

O. On Uniform Speed in Commercial Testing.

P. On Fireproofing Materials.

Q. On Standard Specifications for the Grading of Structural Timber.

R. On Boiler Inspection.

S. On Waterproofing Materials.

T. On the Tempering and Testing of Steel Springs and Standard Specifications for Spring Steel.

U. On Standard Specifications and Tests for Wire Rope.

Publications.—The publications of the Society appeared originally at irregular intervals in the form of bulletins. Twenty-eight (28) bulletins, containing a total of 266 pages, were thus issued. In 1902 it was decided to publish the Proceedings thereafter in the form of annual volumes. In passing to this new plan

of publication the twenty-eight bulletins previously issued were counted collectively as Volume I. The first of the annual volumes, designated Volume II and issued in 1902, contains 388 pages; volume III, issued in 1903, contains 490 pages; volume IV, issued in 1904, contains 655 pages.*

A notable work of the Society is the framing and adoption of Standard Specifications for important commercial products. The list of standard specifications thus far adopted by the Society is as follows:

1. Standard Specifications for Structural Steel for Bridges.
2. Standard Specifications for Structural Steel for Ships.
3. Standard Specifications for Structural Steel for Buildings.
4. Standard Specifications for Open Hearth Boiler Plate and Rivet Steel.
5. Standard Specifications for Steel Rails.
6. Standard Specifications for Steel Splice Bars.
7. Standard Specifications for Steel Axles.
8. Standard Specifications for Steel Tires.
9. Standard Specifications for Steel Forgings.
10. Standard Specifications for Steel Castings.
11. Standard Specifications for Wrought Iron.
12. Standard Specifications for Foundry Pig Iron.
13. Standard Specifications for Cast Iron Pipe and Special Castings.
14. Standard Specifications for Locomotive Cylinders.
15. Standard Specifications for Cast Iron Car Wheels.
16. Standard Specifications for Malleable Castings.
17. Standard Specifications for Gray Iron Castings.
18. Standard Specifications for Cement.

* For Table of Contents and Price List of Previous Publications, see pp. 533-539.

OFFICERS

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

PRESIDENT,

CHARLES B. DUDLEY.

VICE-PRESIDENT,

R. W. LESLEY.

SECRETARY-TREASURER,

EDGAR MARBURG.

Office: University of Pennsylvania, Philadelphia, Pa.

MEMBERS OF THE EXECUTIVE COMMITTEE:

Term Expiring in 1906.

JAMES CHRISTIE, HENRY M. HOWE.

Term Expiring in 1907.

W. A. BOSTWICK, JOHN MCLEOD.

STANDING COMMITTEES.

COMMITTEE ON FINANCE.

JOHN MCLEOD, *Chairman*, W. A. BOSTWICK.
R. W. LESLEY.

COMMITTEE ON MEMBERSHIP.

JAMES CHRISTIE, *Chairman*, R. W. LESLEY,
EDGAR MARBURG.

COMMITTEE ON PUBLICATIONS.

HENRY M. HOWE, *Chairman*, W. A. BOSTWICK.
EDGAR MARBURG.

LIST OF MEMBERS

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

Affiliated with the International Association for Testing Materials.

Members holding membership also in the International Association are distinguished thus (*).

Contributing members are distinguished thus (†).

ELECTED.

1904. *ABBOTT, L. S. Industrial Engineer, 770 West Adams Street, Chicago, Ill.

1902. ACKERMAN, ERNEST R. President, Lawrence Cement Company, 1 Broadway, New York, N. Y.

1904. ACKERMAN, IRA J. Chemist for Pratt and Lambert, 79–97 Tonawanda Street, Buffalo, N. Y.

1905. ADAIR, ARTHUR P. Civil Engineer, Room 327, Sonna Block, Boise, Idaho.

1904. ADAMS, HUGH W. Eastern Agent, Sloss-Sheffield Steel and Iron Company, 15 Beekman Street, New York, N. Y.

1898. *AERTSEN, GUILLIAEM. General Manager, Latrobe Steel Company, 1200 Girard Building, Philadelphia, Pa.

1904. AIKEN, CHARLES W. Consulting Engineer, 82 Washington Street, New York, N. Y.

1902. AIKEN, W. A. General Inspector of Material, Rapid Transit Railroad Commission of New York, 613 Empire Building, Pittsburg, Pa.

1902. *†AJAX METAL COMPANY. G. H. Clamer, Second Vice-President and Secretary, 46 Richmond Street, Philadelphia, Pa.

1904. ALLCOTT, F. L. Engineer of Tests, Chicago, Milwaukee and St. Paul Railway, Milwaukee, Wis.

1903. ALLEN, A. W. Superintendent, Steel Department, Pencoyd Iron Works, 267 Rochelle Avenue, Wissahickon, Philadelphia, Pa.

1905. ALLEN, HENRY C. Special Deputy State Engineer, DeGraaf Building, Albany, N. Y.

1904. ALLEN, WALTER H. Civil Engineer, United States Navy, Navy Yard, New York, N. Y.

ELECTED.

1905. AMERICAN ASPHALTUM AND RUBBER COMPANY. T. J. Hill, President, 721 Woman's Temple, Chicago, Ill.

1902. AMERICAN BRIDGE COMPANY. C. C. Schneider, Consulting Engineer, Fifteenth and Chestnut Streets, Philadelphia, Pa.

1904. *AMERICAN BUREAU OF INSPECTION AND TESTS. E. B. Wilson, Secretary and Treasurer, 930 Monadnock Block, Chicago, Ill.

1898. *AMERICAN FOUNDRYMEN'S ASSOCIATION. Richard Moldenke, Secretary, Watchung, N. J.

1905. AMERICAN IRON AND STEEL MANUFACTURING COMPANY. H. M. Sternbergh, Vice-President and General Manager, Reading, Pa.

1904. *AMERICAN MACHINIST. Fred. J. Miller, Editor, 63 Park Row, New York, N. Y.

1897. AMERICAN SOCIETY OF MECHANICAL ENGINEERS. F. R. Hutton, Secretary, 12 West Thirty-first Street, New York, N. Y.

1900. AMERICAN STEEL AND WIRE COMPANY. F. H. Daniels, Chief Engineer, Worcester, Mass.

1905. *ANDERSON, HAROLD BENTLEY. Mechanical Engineer, The Winton Motor Carriage Company, Cleveland, O.

1897. ANDERSON, R. WILSON. Superintendent, Open-Hearth Plant, Carbon Steel Company, Pittsburg, Pa.

1904. ANGUS, W. F. Engineer, Montreal Steel Works, Limited, Montreal, Canada.

1902. ARNOLD, CHARLES E. Chemist, Experimental Department, duPont Company, Wilmington, Del.

1903. ATKINSON, EDWARD. Director, Insurance Engineering Sta tion, 31 Milk Street, Boston, Mass.

1904. AVERILL, F. L. Civil Engineer, Washington Representative of Robert W. Hunt and Company, Room 220, Colorado Building, Washington, D. C.

1905. AVIS, JAMES L., JR. Mechanical Engineer, Robert W. Hunt and Company, 123 Mail Avenue, Elmwood Place, O.

1904. AYLETT, PHILLIP. Bridge Engineer, Seaboard Air Line Railway, Portsmouth, Va.

1902. *BAILEY, J. B. Treasurer and General Manager, Central Iron and Steel Company, Harrisburg, Pa.

1903. BAKENHUS, R. E. Civil Engineer, United States Navy-In charge of Engineering Woik, Naval Training Station, Newport, R. I.

ELECTED.

1903. BAKER, IRA O. Professor of Civil Engineering, University of Illinois, Champaign, Ill.

1904. BAKER AND CO., W. E. Engineers, 27 William Street, New York, N. Y.

1904. BALDWIN, STEPHEN W. Mechanical Engineer, Pennsylvania Steel Company and Maryland Steel Company, Sparrows Point, Md.

1904. *BARBER ASPHALT PAVING COMPANY. J. L. Rake, General Agent, Land Title Building, Philadelphia, Pa.

1898. BARBOUR, FRANK A. Civil Engineer, Snow and Barbour, 1121 Tremont Building, Boston, Mass.

1904. *BARNES, CHARLES B. 360 East Sixty-second Street, Chicago, Ill.

1904. *BARNSLEY, GEORGE T. Resident Engineer, in Charge of Construction, Wabash Pittsburg Terminals, Wabash Building, Pittsburg, Pa.

1905. BARRETT MANUFACTURING COMPANY, Fred L. Kane, Manager, 17 Battery Place, New York, N. Y.

1904. *BASQUIN, OLIN H. Associate Professor of Physics, Northwestern University, Evanston, Ill.

1903. *BASSETT, WILLIAM H. Chemist in charge of Laboratories, Coe Brass Manufacturing Company, Torrington, Conn.

1903. BATEMAN, F. W. Civil Engineer, Clinton, Mass.

1904. BECK, WESLEY J. Superintendent, Electrical Department, American Rolling Mill Company, Middletown, Ohio.

1903. BECKETT, JAMES A. General Superintendent, Walter A. Wood Mower and Reaper Company, Hoosick Falls, N. Y.

1904. BEEBE, T. E. Superintendent, International Cement Company, Elizabeth, Pa.

1903. BENTLEY, ROBERT. Secretary and General Manager, Ohio Iron and Steel Company, Lowellville, O.

1902. *BERGER, BERNT. Civil Engineer, Assistant Engineer to Theodore Cooper, 45 Broadway, New York, N. Y.

1904. *BERGQUIST, J. G. Superintendent, Cement Plant, Illinois Steel Company, Chicago, Ill.

1904. *BERLE, KORT. Chief Structural Engineer, Supervising Architect's Office, Washington, D. C.

1903. BERRALL, JAMES. Civil Engineer, Bond Building, Washington, D. C.

1905. BERRY, H. C. Instructor in Civil Engineering, University of Pennsylvania, Philadelphia, Pa.

ELECTED.

1898. BETHLEHEM STEEL COMPANY. E. O'C. Acker, Assistant General Superintendent, South Bethlehem, Pa.

1904. BETTS, H. S. Testing Engineer, Bureau of Forestry, Washington, D. C.

1904. BIRD, ROBERT M. Superintendent, Treatment Department, Bethlehem Steel Company, 433 Brodhead Avenue, South Bethlehem, Pa.

1905. BIRKINBINE, JOHN. Consulting Engineer, Odd Fellows' Temple, Philadelphia, Pa.

1896. BISSELL, GEORGE W. Professor of Mechanical Engineering, Iowa State College, Ames, Iowa.

1903. *BIXBY, W. H. Colonel, Corps of Engineers, United States Army, Room 504, Federal Building, Chicago, Ill.

1904. BLACK, ADOLPH. Instructor in Civil Engineering, Columbia University, New York, N. Y.

1904. BLANCH, JOSEPH C. Superintendent, Blanchite Process Paint Company, 42 Broadway, New York, N. Y.

1905. BLAUVELT, W. H. Managing Engineer, Semet Solvay Company, Syracuse, N. Y.

1905. BLAUVELT, WARREN S. Superintendent, Coke Oven Department, The Solvay Process Company, Detroit, Mich.

1902. BLISS, COLLINS P. Professor of Mechanical Engineering and Director of Testing Laboratory, New York University, University Heights, New York, N. Y.

1903. BOCKING, RUDOLPH. Halbergerhutte, Post Brebach, Germany.

1905. BOLE, WM. A. Manager of Works, Westinghouse Machine Company, East Pittsburg, Pa.

1903. *BOLLER AND HODGE. Consulting Engineers, 1 Nassau Street, New York, N. Y.

1902. BONZANO, A. President, Bonzano Rail-Joint Company, 331 South Eighteenth Street, Philadelphia, Pa.

1896. BOOTH, GARRETT AND BLAIR. Engineers and Chemists, 406 Locust Street, Philadelphia, Pa.

1905. *BORGNER, CYRUS. Fire Brick and Cement Manufacturer, Twenty-third Street above Race Street, Philadelphia, Pa.

1904. *BOSTWICK, W. A. (*Member of Executive Committee*) Metallurgical Engineer, Carnegie Steel Company, Pittsburg, Pa.

1905. BOUGHTON, W. H. Professor of Civil Engineering, West Virginia University, Morgantown, W. Va.

ELECTED.

1904. *BOWMAN, AUSTIN LORD. Consulting Engineer; Bridge Engineer, Central Railroad Company of New Jersey, 29 Broadway, New York, N. Y.

1905. BOYER, EDWARD D. Cement Expert, Atlas Portland Cement Company, Catasauqua, Pa.

1902. BOYNTON, C. W. Chief Inspector, Cement Department, Illinois Steel Company, 1063 The Rookery, Chicago, Ill.

1900. BRAINE, L. F. General Manager, Continuous Rail-Joint Company, Newark, N. J.

1898. BRAMWELL, JOSEPH W. Treasurer and Engineer, Columbia Graphite Company, 909 Walnut Street, Philadelphia, Pa.

1904. BREGOWSKY, IVAN M. Metallurgist, Crane Company, 51 Judd Street, Chicago, Ill.

1905. BRITTEN, CLARENCE R. Chemist, 27 Harrison Street, New York, N. Y.

1899. BROADHURST, W. H. Chemist, Department of Public Works, Municipal Building, Brooklyn, N. Y.

1905. BROWN AND COMPANY, INCORPORATED, Wayne Iron and Steel Works. James Neale, Secretary, Pittsburg, Pa.

1903. *BROWN, CHARLES CARROLL. Editor, *Municipal Engineering Magazine*, 408 Commercial Club Building, Indianapolis, Ind.

1904. BROWN, JOHN G. General Manager, Unit Concrete-Steel Frame Company, 1416 Commonwealth Building, Philadelphia, Pa.

1904. BROWN, SAMUEL A. Inspector of Cement, Philadelphia Rapid Transit Company, 1526 South Thirteenth Street, Philadelphia, Pa.

1905. BROWN, WM. L. Test Department, Pennsylvania Railroad, Altoona, Pa.

1903. *BRUNNER, JOHN. Assistant General Superintendent, Illinois Steel Company, 1732 Chicago Avenue, Evanston, Ill.

1905. BUCK, R. S. Consulting Engineer, Department of Bridges, New York, Park Row Building, New York, N. Y.

1903. BUCKLEY, E. R. Director, Missouri Bureau of Geology and Mines, State Geologist, Rolla, Mo.

1905. BUEL, HAMBDEN. Chemist, Central Iron and Coal Company, Tuscaloosa, Ala.

1904. *BUNNELL, F. O. Engineer of Tests, Chicago, Rock Island and Pacific Railway, Forty-seventh Street and Wentworth Avenue, Chicago, Ill.

ELECTED.

1902. BURDETT, F. A. Civil Engineer, 3 East Thirty-third Street, New York, N. Y.

1903. BURNHAM, RAYMOND. Associate Professor of Experimental Engineering, Armour Institute of Technology, Chicago, Ill.

1899. *BURR, WILLIAM H. Professor of Civil Engineering, Columbia University, New York, N. Y.

1905. BUSS, EDWARD A. Consulting Engineer, 85 Water Street, Boston, Mass.

1903. *BUZZI, P. D. Superintendent of Engineering Laboratory, Tacon 3, Havana, Cuba.

1904. CAHALL, W. H. Superintendent, Boiler Department, 706 Lake Avenue, Racine, Wis.

1904. CAIRNS, EDWARD T. General Inspector, Improved Risk Department, The North British and Mercantile Insurance Company, 159 La Salle Street, Chicago, Ill.

1902. CAMBIER, JACOB. Chemist, Colorado Fuel and Iron Company, 910 Spruce Street, Pueblo, Colo.

1899. *†CAMBRIA STEEL COMPANY. George E. Thackray, Structural Engineer, Johnstown, Pa.

1896. CAMPBELL, H. H. Superintendent and General Manager, The Pennsylvania Steel Company, Steelton, Pa.

1903. *CAMPBELL, WILLIAM. Instructor in Metallurgy, School of Mines, Columbia University, New York, N. Y.

1898. CAPP, JOHN A. Engineer, Testing Laboratory, General Electric Company, Schenectady, N. Y.

1898. †CARNEGIE STEEL COMPANY. W. A. Bostwick, Metallurgical Engineer, Pittsburg, Pa.

1903. *CARNEY, F. D. Assistant Superintendent, The Pennsylvania Steel Company, Steelton, Pa.

1902. CARPENTER, LOUIS G. Professor of Civil and Irrigation Engineering, and Director of Experiment Station, Fort Collins, Colo.

1895. CARPENTER, ROLLA C. Professor Experimental Engineering, Cornell University, 31 Eddy Street, Ithaca, N. Y.

1903. *CARPENTER STEEL COMPANY, THE. George W. Sargent Metallurgist, Reading, Pa.

1904. *CARTER, J. G. Inspector of Sand and Cement, Washington Aqueduct, 2728 Pennsylvania Avenue, N. W., Washington, D. C.

1899. CARTER, ROBERT A. President, Monongahela Iron and Steel Company, Box 215, Pittsburg, Pa.

ELECTED.

1903. CARTLIDGE, C. H. Bridge Engineer, Chicago, Burlington and Quincy Railroad, 209 Adams Street, Chicago, Ill.

1905. CATLETT, CHARLES. Chemist and Geologist, Staunton, Va.

1905. CENTRAL IRON AND COAL COMPANY. J. Lodge, President, Tuscaloosa, Ala.

1902. *†CENTRAL IRON AND STEEL COMPANY. James B. Bailey, Treasurer and General Manager, Harrisburg, Pa.

1905. CHAMBERLAIN, PAUL R. Chemist, The Portland Cement Company, Portland, Col.

1905. CHAMPION, E. C. Superintendent, Kansas Portland Cement Company, Iola, Kans.

1904. CHEESMAN, FRANK P. National Paint Works, 92 William Street, New York, N. Y.

1905. CHRISTIAN, EDMUND. Manager, Norfolk Creosoting Company, Buell, Va.

1898. CHRISTIE, JAMES (*Member of Executive Committee*). Mechanical Engineer, 100 Rochelle Avenue, Wissahickon, Philadelphia, Pa.

1900. *CHURCHILL, CHARLES S. Chief Engineer, Norfolk and Western Railway, Roanoke, Va.

1905. *CIVIL ENGINEERS' CLUB OF CLEVELAND, THE. Jos. C. Beardsley, Secretary, 1200 Schofield Building, Cleveland, O.

1905. CLAPP, WILFRED A. Civil Engineer, United States Quartermaster's Department, 103 Sherman Street, Portland, Me.

1900. *CLARK, F. H. General Superintendent of Motive Power, Chicago, Burlington and Quincy Railroad, 209 Adams Street, Chicago, Ill.

1905. CLARKE, D. D. Civil Engineer, Water Board, City Hall, Portland, Ore.

1905. CLARKE, ST. JOHN. Chief Engineer, New York and Long Island Railroad, 16 East Forty-second Street, New York, N. Y.

1904. *CLARKSON MEMORIAL SCHOOL OF TECHNOLOGY, THOMAS S. William S. Aldrich, Director, Potsdam, N. Y.

1905. CLEMENTS, FRANK O. Principal Assistant Chemist, Union Pacific Railroad, 2912 Mason Street, Omaha, Neb.

1904. CLIFTON, CHARLES H. First Assistant, Philadelphia Municipal Testing Laboratory, 318 City Hall, Philadelphia, Pa.

1905. COE, EDWARD K. Assistant City Engineer, 1411 East Third Street, Duluth, Minn.

ELECTED.

1899. COLBY, ALBERT LADD. International Nickel Company, 43 Exchange Place, New York, N. Y.

1899. COLBY, J. ALLEN. Inspecting Engineer, Witherspoon Building, Philadelphia, Pa.

1904. COLLES, GEORGE W. Consulting Mechanical and Electrical Engineer, 408 Alhambra Building, Milwaukee, Wis

1900. *COLORADO FUEL AND IRON COMPANY. C. S. Robinson, General Manager, Iron Department, Denver, Colo.

1905. CONDIT, E. A., JR. Inspector, Continuous Rail Joint Company, 520 Summer Avenue, Newark, N. J.

1905. CONDIT, FILLMORE. Manager, California Asphaltum Sales Agency, 11 Broadway, New York, N. Y.

1900. *CONDRON, T. L. Consulting Engineer, 1442 Monadnock Building, Chicago, Ill.

1904. CONLIN, FREDERICK. General Manager, Bethlehem Foundry and Machine Company, Lehigh Foundry Company, 355 Market Street, Bethlehem, Pa.

1904. CONNOR, CHARLES E. Assistant Inspector of Buildings of District of Columbia, The Farragut, Washington, D. C.

1904. CONRADSON, P. H. Chief Chemist, Galena Signal Oil Company, Franklin, Pa.

1905. CONVERSE, W. A. Directing Chemist, Dearborn Drug and Chemical Works, 227 to 234 Rialto Building, Chicago, Ill.

1903. COOK, EDGAR S. President, Warwick Iron and Steel Company, Pottstown, Pa.

1899. CORTHELL, E. L. Civil Engineer, 1 Nassau Street, New York, N. Y.

1902. COSBY, SPENCER. Captain, Corps of Engineers, United States Army, care of War Department, Washington, D. C.

1903. COWEN, HERMAN C. Superintendent, Catskill Cement Company, Smith Landing, Greene County, N. Y.

1905. *CRAWFORD, HARRY C. Inspector, Railway Equipments, Fox Chase, Philadelphia, Pa.

1904. *CROWELL, BENEDICT. Mining Engineer, 731 Williamson Building, Cleveland, O.

1903. CROXTON, H. A. President, Massillon Iron and Steel Company, Massillon, O.

1899. *CRUIKSHANK, BARTON. Consulting Engineer, 1813 West Genesee Street, Syracuse, N. Y.

1904. CUMMINGS, ROBERT A. Consulting and Contracting Engineer, 4 Smithfield Street, Pittsburg, Pa.

ELECTED.

1904. CUSHMAN, ALLERTON S. Chemist, Road Material Laboratory, United States Department of Agriculture, Washington, D. C.

1903. DABBS, HAROLD M. L. J. McCloskey and Company, Thirtieth and Locust Streets, Philadelphia, Pa.

1900. *DAVIDSON, GEORGE M. Engineer of Tests, Chicago and Northwestern Railroad, Chicago, Ill.

1904. DAVIS, A. P. Assistant Chief Engineer, United States Geological Survey, Washington, D. C.

1904. *DAVIS, CHANDLER. Department of Docks and Ferries, Pier "A," North River, New York, N. Y.

1905. DAVIS, CHARLES HENRY. 25 Broad Street, New York, N. Y.

1904. DAVIS, NATHAN H. President, Diamond State Car Steel Company, Davis Pressed Steel Company, Wilmington, Del.

1903. *DAVIS, WILLIAM R. Chief Bridge Designer, State Engineer's Office, Albany, N. Y.

1904. DAVIS, WILLIAM M. Oil Inspector, in Charge of Lubrication, American Sheet and Tin Plate Company, Sheridanville, Allegheny County, Pa.

1902. *DE ARMOND, W. C. President, Protectus Company, 1103 North American Building, Philadelphia, Pa.

1905. *DEKNIGHT, EDWARD W. President and Manager, Hydrex Felt and Engineering Company, 120 Liberty Street, New York, N. Y.

1905. DEWOLF, R. D. Electrical Engineer, Westinghouse Electric and Manufacturing Company, 508 Rebecca Street, Wilkinsburg, Pa.

1904. DE WYRALL, CYRIL. Master Painter, Interborough Rapid Transit Company, New York City. *For Mail*, Ridgefield Park, N. J.

1899. *DEANS, JOHN STERLING. Chief Engineer, Phœnix Bridge Company, Phœnixville, Pa.

1904. DEPARTMENT OF ENGINEERING, TUFTS COLLEGE. Gardner C. Anthony, Dean, Tufts College, Mass.

1902. DERLETH, CHARLES, JR. Professor of Structural Engineering, University of California, Berkeley, Cal.

1904. DETROIT GRAPHITE MANUFACTURING COMPANY. F. W. Davis, Jr., Second Vice-President, 141 Broadway, New York, N. Y.

ELECTED.

1903. *DEVERELL, H. F. Secretary, Otis Steel Company, Cleveland, O.

1905. DICKERSON, W. H. Assistant Engineer of Tests, Union Pacific Railroad, 3708 North Twenty-first Street, Omaha, Neb.

1903. *DIEDERICHS, H. Assistant Professor of Experimental Engineering, Cornell University, 913 North Aurora Street, Ithaca, N. Y.

1903. *DILLER, H. E. Western Electric Company, Chicago, Ill.

1903. DIMMICK, J. K. Broker, J. K. Dimmick and Company, 1022 New Land Title Building, Philadelphia, Pa.

1904. DINAN, EDWARD. Chemist, Edison Portland Cement Company, 230 East Third Street, South Bethlehem, Pa.

1902. DIXON CRUCIBLE COMPANY, JOSEPH. Malcolm McNaughton, Superintendent, Paint and Lubricating Department, Jersey City, N. J.

1903. †DIXON, R. M. Vice-President, The Safety Car Heating and Lighting Company, 160 Broadway, New York, N. Y.

1901. *DOBLE, WILLIAM A. President, Abner Doble Company, 200 Fremont Street, San Francisco, Cal.

1904. *DOMINION BRIDGE COMPANY. Phelps Johnson, Manager, Montreal, Canada.

1905. *DONOHOE, JOHN P. Vice-President and General Manager, Donohoe Coke Company, Greensburg, Pa.

1898. *DOW, A. W. Inspector of Asphalts and Cements, District of Columbia, Washington, D. C.

1903. DRAKE, C. F. Western Manager, Crowell, Dickman and Kenyon, Inspecting Engineers, 1120 Rookery Building, Chicago, Ill.

1903. DRUMMOND, M. J. President, Glamorgan Pipe and Foundry Company, 192 Broadway, New York, N. Y.

1905. DUBBS, C. P. General Manager, Globe Asphalt Company, 310 Togo Building, Los Angeles, Cal.

1904. DUBBS, J. A. President, Globe Asphalt Company, 405 Bakewell Building, Pittsburg, Pa.

1902. DU COMB, W. C., JR. Engineer of Tests, Richlé Brothers Testing Machine Company, 1424 North Ninth Street, Philadelphia, Pa.

1896. *†DUDLEY, CHARLES B. (*President*). Chemist, Pennsylvania Railroad, Altoona, Pa.

1902. DUDLEY, P. H. Consulting Engineer, 80 Pine Street, New York, N. Y.

ELECTED.

1901. DUFOUR, F. O. 534 Ontario Street, South Bethlehem, Pa.

1902. DUMARY, L. HENRY. President, The Helderberg Cement Company, 38 State Street, Albany, N. Y.

1902. DUNBAR, W. O. Assisting Engineer, Testing Department, Pennsylvania Railroad, Altoona, Pa.

1904. DUNCKLEE, JOHN B. Civil and Consulting Engineer, 35 Fairview Avenue, South Orange, N. J.

1904. DUNN, W. R. Superintendent, Vulcanite Portland Cement Company, Phillipsburg, N. J.

1905. DUNNING, HUBERT. National Lead Company, 100 William Street, New York, N. Y.

1904. DURYEE, E. Cement Expert, United States Reclamation Service, Roosevelt, Ariz.

1904. DWIGHT, THEODORE. Electrical Engineer, Post Office Box 223, New York, N. Y.

1905. EAGLE WHITE LEAD COMPANY. F. J. Baringer, Chemist, Cincinnati, O.

1902. EASBY, M. WARD. Consulting Engineer, 909 Crozer Building, Philadelphia, Pa.

1905. *EATON, LEWIS G. Plainville, Conn.

1905. EDGERLY, DANIEL W. Manager, Technical Paint Department, Chilton Paint Company, 69 Cortlandt Street, New York, N. Y.

1905. EDWARDS, V. E. Mechanical Engineer, Morgan Construction Company, Worcester "A," Mass.

1902. EDWARDS, WARRICK R. Assistant to Engineer of Bridges and Buildings, Baltimore and Ohio Railroad, Mount Royal Station, Baltimore, Md.

1905. *EHRENFELD, CHARLES H. Chemist, York Manufacturing Company, York, Pa.

1904. *EIDLITZ, OTTO M. Civil Engineer, 489 Fifth Avenue, New York, N. Y.

1903. ELDRIDGE, G. F. B. Nicoll and Company, 59 Wall Street, New York, N. Y.

1905. ELLIS, THEODORE H. District Manager, Sun Company, 334 Hughes Avenue, Baltimore, Md.

1896. *ELY, THEODORE N. Chief of Motive Power, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

1905. *ELZNER, A. O. Architect, 136 Ingalls Building, Cincinnati, O.

ELECTED.

1905. EMERSON, GEORGE H. Vice-President, North Western Lumber Company, Hoquiam, Wash.

1898. ENGINEERING RECORD. 114 Liberty Street, New York, N. Y.

1905. ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA. F. V. McMullin, Secretary, 410 Penn Avenue, Pittsburg, Pa.

1905. ENGINEERS' CLUB OF CINCINNATI. C. H. Meeds, Secretary-Treasurer, Post Office Box 333, Cincinnati, O.

1905. ENRIGHT, BERNARD. Chief Chemist, Virginia Portland Cement Company, Fordwick, Augusta County, Va.

1903. *ERLANDSEN, OSCAR. Chief Engineer, O'Rourke Engineering Construction Company, 1 West Thirty-fourth Street, New York, N. Y.

1903. ESTERLINE, J. WALTER. Assistant Professor of Electrical Engineering, Purdue University, Lafayette, Ind.

1905. *ESTILL, HOWARD S. Assistant Engineer, Chesapeake and Ohio Railway, Richmond, Va.

1905. EVANS, D. T. General Manager, The Mount Carbon Company, Limited, Powellton, W. Va.

1904. EVANS, S. M. Manager New York Office, Picher Lead Company, 100 William Street, New York, N. Y.

1904. EWEN, JOHN M. Vice-President, Thompson-Starrett Company, 1402 Railway Exchange, Chicago, Ill.

1905. EWING, W. W. Treasurer, The Thomas J. Brady Company, 1123 Broadway, New York, N. Y.

1904. *FACKENTHAL, JR., B F. President, Thomas Iron Company, Easton, Pa.

1903. FACULTY APPLIED SCIENCE, MCGILL UNIVERSITY. Henry T. Bovey, Dean, Montreal, Can.

1905. FALK, MYRON S. Instructor in Civil Engineering, Columbia University, 44 West Fifty-third Street, New York, N. Y.

1902. FALKENAU, A. President, Falkenau-Sinclair Machine Company, Testing Machines, 109 North Twenty-second Street, Philadelphia, Pa.

1902. FARREL FOUNDRY AND MACHINE COMPANY. Herbert E. Field, Metallurgist, Ansonia, Conn.

1902. FAY, HENRY. Assistant Professor of Analytical Chemistry and Metallography, Massachusetts Institute of Technology, Boston, Mass.

ELECTED.

1903. FENNER, L. M. Chemist, New York Air Brake Company, 10 Boyd Street, Watertown, N. Y.

1905. FERNOW, B. E. Consulting Forest Engineer, 42 Broadway, New York, N. Y.

1905. *FINN, GEORGE H. General Manager, The New England Gas and Coke Company, Old South Building, Boston, Mass.

1903. FITZGERALD, FRANCIS A. J. Chemical Engineer, P. O. Box 118, Niagara Falls, N. Y.

1899. FLAGG, STANLEY G., JR. Stanley G. Flagg and Company, Nineteenth Street and Pennsylvania Avenue, Philadelphia, Pa.

1904. *FLEMING, HENRY S. Consulting Engineer, 1 Broadway, New York, N. Y.

1903. FLETCHER, AUSTIN B. Secretary, Massachusetts Highway Commission, 20 Pemberton Square, Boston, Mass.

1904. FORD, ALLEN P. Metallurgist, Crane Company, 52 Judd Street, Chicago, Ill.

1901. FORREST, C. N. Chief Chemist, New York Testing Laboratory, Long Island City, N. Y.

1903. FORSYTH, WILLIAM. Mechanical Engineer, *Railway Age*, Chicago, Ill.

1904. FOSTER, W. C. Vice-President and General Manager, Glamorgan Pipe and Foundry Company, 182 Broadway, New York, N. Y.

1905. FOX, ADAM H. Superintendent, Forge Department, American Bridge Company, 233 Rochelle Avenue, Wissahickon, Philadelphia, Pa.

1898. FRANKLIN INSTITUTE. William H. Wahl, Secretary, 15 South Seventh Street, Philadelphia, Pa.

1905. *FRAZIER, H. Consulting Engineer, Seaboard Air Line Railway, 812 American Bank Building, Richmond, Va.

1905. *FREEMAN, JOHN R. Consulting Engineer, 815 Barrigan Building, Providence, R. I.

1903. FRENCH, JAMES B. Bridge Engineer, The Long Island Railroad Company, Jamaica, N. Y.

1903. FRENCH, LESTER G. Editor, *Machinery*, 66 Broadway, New York, N. Y.

1904. FROEHLING AND ROBERTSON. Analytical Chemists, Chemical and Mining Engineers, 17 South Twelfth Street, Richmond, Va.

ELECTED.

1905. *FRY, LAWFORD H. Engineer of Tests, Baldwin Locomotive Works, 500 North Broad Street, Philadelphia, Pa.

1903. *FULLER, ALMON H. Professor of Civil Engineering, Washington University, University Station, Seattle, Wash.

1904. *FULLER, WM. B. Consulting Civil Engineer, 170 Broadway, New York, N. Y.

1905. *GAEHR, DAVID. 683 Gordon Avenue, Cleveland, O.

1903. GALBRAITH, J. Principal, School of Practical Science, Toronto, Can.

1905. *GARFIELD, ALEXANDER STANLEY. Chief Engineer, Cie. Francaise Thomson-Houston; Consulting Engineer, Mediterranean Thomson-Houston Company and General Electric Company. 67 Avenue De Malakoff, Paris France.

1905. GARLINGHOUSE, F. L. Structural Engineer, Jones & Laughlin Steel Company, Glenshaw, Pa.

1905. *GAY, MARTIN. Assistant Engineer, Department of Bridges, New York City, 21 Park Row, New York, N. Y.

1905. GERLACH, O. General Superintendent, Iola Portland Cement Company, Iola, Kan.

1902. *GERSTELL, A. F. Vice-President and General Manager, Alpha Portland Cement Company, Alpha, N. J.

1902. GIBBS, A. W. General Superintendent of Motive Power Pennsylvania Railroad, Altoona, Pa.

1902. *GIBBS, GEORGE. First Vice-President, Westinghouse, Church, Kerr and Company, 10 Bridge Street, New York, N. Y.

1905. GIESLER, ARTHUR. Chief Engineer, Platt Iron Works Company, Dayton, O.

1905. *GILBERT, H. GRAY. Draftsman, Office of Designing Engineer, New York Central and Hudson River Railroad, Forty-third Street and Madison Avenue, New York, N. Y.

1905. GILL, AUGUSTUS H. Assistant Professor of Technical Analysis, Massachusetts Institute of Technology, Boston, Mass.

1903. GILMOUR, EDWARD B. Superintendent, The Cook Heater Company, 301 North Perry Avenue, Peoria, Ill.

1904. *GIROUX, GUSTAVE. Inspector of Materials, Canadian Pacific Railway Company, 5 Craig Street, Montreal, P. Q., Canada.

ELECTED.

1904. *GLASGOW IRON COMPANY. C. B. Shoemaker, President, 603-608 Harrison Building, Philadelphia, Pa.

1904. *GODWIN, W. S. General Manager, American Block Press Company, 404 Temple Bar Building, Brooklyn, N. Y.

1904. GOODMAN, CARLTON M. Chemist, Alma Cement Company, Wellston, O.

1904. †GOODNOW, C. A. General Manager, Chicago and Alton Railroad, Chicago, Ill.

1904. GOODSPEED, G. M. Metallurgist, National Tube Company, McKeesport, Pa.

1904. GOODWIN, H. S. Bridge Inspector, 201 North Owen Avenue, Lansdowne, Pa.

1896. *GOSS, WILLIAM F. M. Dean of the Schools of Engineering, Purdue University, Lafayette, Ind.

1905. GOW, CHARLES R. Civil Engineer and Contractor, 79 Milk Street, Boston, Mass.

1904. GOWEN, CHARLES S. Engineer, New Croton Dam, Ossining, N. Y.

1903. GRANTHAM, HERBERT T. Chief Engineer, Belmont Iron Works, 1622 Real Estate Trust Building, Philadelphia, Pa.

1899. *GRAVES, EDWIN D. Chief Engineer, Connecticut River Bridge and Highway District, 650 Main Street, Hartford, Conn.

1903. *GRAY, JOHN LATHROP. Assistant Superintendent, Tidewater Oil Company, East Twenty-second Street, Bayonne, N. J.

1896. *GRAY, THOMAS. Professor of Dynamic Engineering, Rose Polytechnic Institute, Terre Haute, Ind.

1905. *GRAY, THOMAS TARVIN. Chemist, Tide Water Oil Company, East Twenty-second Street, Bayonne, N. J.

1904. *GREEN, MORRIS M. Professor of Mechanical Engineering, Colorado State University, Boulder, Col.

1905. GREENE, GEO. W. Inspecting Engineer, American Bureau of Inspection and Tests, Heeren Building, Eighth and Penn Avenue, Pittsburg, Pa.

1904. GREENMAN RUSSELL S. Assistant Engineer, State Engineer's Department, Albany, N. Y.

1902. GREINER, J. E. Assistant Chief Engineer, Baltimore and Ohio Railroad, Baltimore, Md.

1904. *GREGORY, W. B. Associate Professor of Experimental Engineering, Tulane University of Louisiana, New Orleans, La.

ELECTED.

1905. GRISWOLD, R. E. Superintendent, Barber Asphalt Paving Company, Madison, Ill.

1904. GUPPY, BENJ. W. Bridge Engineer, Maine Central Railroad, 238 St. John Street, Portland, Maine.

1901. HAGAR, EDWARD M. Manager, Cement Department, Illinois Steel Company, 1060 The Rookery, Chicago, Ill.

1905. HALDEMAN, HORACE L. Treasurer, Pulaski Iron Company, 1008 Real Estate Trust Building, Philadelphia, Pa.

1905. HALL, WILLIAM L. Assistant Forester, in Charge of Office of Forest Products, Bureau of Forestry, United States Department of Agriculture, Washington, D. C.

1903. *HALLETT, NELSON A. Cement Inspector, 1 Ashburton Place, Boston, Mass.

1905. HAMILTON, M. C. Engineer, Maintenance of Way, Interborough Rapid Transit Company, 2434 Park Row Building, New York, N. Y.

1904. HAMMOND, R. R. Second Vice-President, St. Louis and San Francisco Railroad, St. Louis, Mo.

1903. *HANCOCK, E. L. Instructor of Applied Mechanics, Purdue University, Lafayette, Ind.

1905. *HAND, ELWOOD STOKES. Installation Engineer, Mississippi Wire Glass Company, 277 Broadway, New York, N. Y.

1905. HANNA, W. C. Chemist, California Portland Cement Company, Colton, Cal.

1905. HARDING, CHESTER. Captain, Corps of Engineers, United States Army, District Building, Washington, D. C.

1904. *HARDING, JAMES J. Engineer of Masonry Construction, Chicago, Milwaukee and St. Paul Railway, 1232 Railway Exchange Building, Chicago, Ill.

1902. HARDING, W. H. President, Bonneville Portland Cement Company, 2029 Land Title Building, Philadelphia, Pa.

1903. *HARGROVE, JULIAN O. Assistant Inspector of Asphalt and Cement, 1603 O Street, N. W., Washington, D. C.

1902. HARRIMAN, N. F. Chemist and Engineer of Tests, Union Pacific Railroad, Omaha, Neb.

1905. HARRISON, ARTHUR B. Manager, Paint Department, Clifford L. Miller and Company, 125 East Twenty-third Street, New York, N. Y.

1902. *HARTFORD STEAM BOILER INSPECTION AND INSURANCE COMPANY. Francis B. Allen, Vice-President, Hartford, Conn.

ELECTED.

1904. HARTLEY, HENRY J. Superintendent, Boiler Department, William Cramp and Sons, 1624 Oxford Street, Philadelphia.

1898. HARTRANFT CEMENT COMPANY, WILLIAM G. Sole Selling Agent for Old Dominion and Phœnix Portland Cement, Real Estate Trust Building, Philadelphia, Pa.

1905. *HARVARD COLLEGE LIBRARY. Alfred C. Potter, Assistant Librarian, Cambridge, Mass.

1898. *HATT, WILLIAM K. Professor of Applied Mechanics, Purdue University, Lafayette, Ind.

1904. HAWXHURST, ROBERT. Engineer, 620 North C Street, Tacoma, Wash.

1904. HAYES, HAMMOND V. Engineer, American Telephone and Telegraph Company, 125 Milk Street, Boston, Mass.

1903. *HEARNE, W. W. Member of firm Mathew Addy and Company, 1625 Real Estate Trust Building, Philadelphia, Pa.

1905. HECKEL, G. B. Editor, *Drugs, Oils and Paints*, 634–36 The Bourse, Philadelphia, Pa.

1904. HEIDENREICH, E. LEE. Consulting Engineer, 721 The Rookery, Chicago, Ill.

1904. *HELWIG, ALFRED. Testing Engineer, Brooklyn Heights Railroad Company, Central Power Station, Second Street and Third Avenue, Brooklyn, N. Y.

1904. HEMSTREET, GEORGE P. Superintendent, Hastings Pavement Company, Hastings-on-Hudson, N. Y.

1903. HENSHAW, JOHN O. Member, N. S. Bartlett and Company, 126 State Street, Boston, Mass.

1904. HERING, RUDOLPH. Hydraulic and Sanitary Engineer, 170 Broadway, New York, N. Y.

1902. HILDRETH, P. S. Consulting and Inspecting Engineer, 32 Broadway, New York, N. Y.

1905. HITCHCOCK, F. C. Engineer, Contractor and Manufacturer, Room 205, 253 Broadway, New York, N. Y.

1904. *HOFF, OLAF. Vice-President, Butler Brothers Construction Company, 1170 Broadway, New York, N. Y.

1902. HOFMAN, H. O. Professor of Metallurgy, Massachusetts Institute of Technology, Boston, Mass.

1903. HOLMES, JOSEPH A. State Geologist of North Carolina, Chapel Hill, N. C.

1904. HOPTON, W. E. Assistant Purchasing Engineer, Solvay Process Company, Syracuse, N. Y.

ELECTED.

1904. How, R. W. Chief Inspector, Bridge Engineer's Office, Long Island Railroad Company, 5 Hanson Place, Brooklyn, N. Y.

1903. Howard, L. E. Superintendent, Simonds Manufacturing Company, Seventeenth Street and Western Avenue, Chicago, Ill.

1896. *Howe, Henry M. (*Past-President*). Professor of Metallurgy, Columbia University, 27 West Seventy-third Street, New York, N. Y.

1904. *Hubbell, C. A. President, R. Almond Manufacturing Company, Brooklyn, N. Y.

1904. Huber, Frederick W. Engineer of Tests, United States Geological Survey, Berkeley, Cal.

1905. *Hudson, H. N. General Manager, Hoyt Metal Company, St. Louis, Mo.

1905. *Hughes, Hector J. Assistant Professor of Hydraulics and Sanitary Engineering, Harvard University, 114 Pierce Hall, Cambridge, Mass.

1905. Hughes and Patterson. Manufacturers of Bar Iron, 800 Richmond Street, Philadelphia, Pa.

1904. *Hull, Geo. H. President, American Pig Iron Storage Warrant Company, 44 Wall Street, New York, N. Y.

1905. Hull, Walter A. General Manager, Shawmut Clay Manufacturing Company, Drummond, Pa.

1904. Hume, A. P. Engineer of Tests, American Bridge Company, Pencoyd, Pa.

1896. *Humphrey, Richard L. Consulting Engineer and Chemist, 1001 Harrison Building, Philadelphia, Pa.

1903. Hunnings, S. V. Engineer of Tests, American Locomotive Company, Pittsburg, Pa.

1905. *Hunt, H. B. General Inspector, American Locomotive Company, Schenectady, N. Y.

1903. *Hunt, Loren E. Civil Engineer, United States Forest Service, Berkeley, Cal.

1899. Hunt Company, Robert W. Inspecting and Testing Engineers, 1121 The Rookery, Chicago, Ill.

1905. Hunter, John Andrew. Assistant Professor of Mechanical Engineering, University of Colorado, Boulder, Col.

1903. Hunter, Joseph W. Engineer and Surveyor, State Highway Commissioner, Harrisburg, Pa.

1899. Huston, Charles L. Vice-President, Lukens Iron and Steel Company, Coatesville, Pa.

ELECTED.

1904. HUTCHINSON, GEORGE W. Engineer of Tests, American Locomotive Company, Richmond Works, Richmond, Va.

1905. HYDE, A. LINCOLN. Assistant Professor of Bridge Engineering, University of Missouri, Columbia, Mo.

1903. HYDE, CHARLES G. Assistant Professor of Sanitary Engineering, University of California, Berkeley, Cal.

1904. *†ILLINOIS CENTRAL RAILROAD COMPANY, J. T. Harahan, Second Vice-President, Chicago, Ill.

1900. †ILLINOIS STEEL COMPANY. P. E. Carhart, Inspecting Engineer, Rookery Building, Chicago, Ill.

1903. INSURANCE ENGINEERING. Franklin Webster, Editor, 120 Liberty Street, New York, N. Y.

1902. INTERNATIONAL ACHESON GRAPHITE COMPANY. Manufacturers of Graphite and Graphite Articles, Niagara Falls, N. Y.

1904. INTERNATIONAL HARVESTER COMPANY. John G. Wood, Second Assistant Manager, Manufacturing Department, 7 Monroe Street, Chicago, Ill.

1902. *IRON TRADE REVIEW, THE. Robert T. Kent, Editor, Cleveland, O.

1896. JARECKI, ALEXANDER. Superintendent, Jarecki Manufacturing Company, Limited, Erie, Pa.

1905. JEFFERS, JOHN M. Oil Inspector, National Tube Company, 1603 Jenny Lind Street, McKeesport, Pa.

1904. *JENKINS, JOEL. President, Round Top Cement Company, 43 Lincoln Street, Montclair, N. J.

1905. JENKINS, FREDERICK E. Vice-President, Round Top Cement Company, Hancock, Md.

1897. JENKINS, JOHN. General Manager, Milton Iron Company Milton, Pa.

1904. JENNINGS, ARTHUR S. Editor, *The Decorator*, 365 Birkbeck Bank Chambers, High Holborn, London, W. C., England.

1900. JEWETT, J. Y. Cement Expert, Reclamation Service, United States Geological Survey, Denver, Col.

1900. JOB, ROBERT. Chemist, Philadelphia and Reading Railway Reading, Pa.

1903. *JOHNSON, ALBERT L. Chief Engineer, Expanded Metal Fire-proofing Company, 606 Century Building, St. Louis, Mo.

ELECTED.

1903. JOHNSON, ARTHUR N. Civil Engineer; Highway Engineer, United States Office of Public Roads, Washington, D. C.

1904. JOHNSON, CHARLES C. Cement Inspector, Boston Transit Commission, 15 Beaver Street, Boston, Mass. *For Mail*, 141 High Street, Danvers, Mass.

1905. *JOHNSON, EDMUND. Cement Chemist, Yankton, S. Dak.

1904. JOHNSON, J. S. A. In charge of Testing Laboratory, Virginia Polytechnic Institute, Blacksburg, Va.

1904. JOHNSON, LEWIS J. Assistant Professor of Civil Engineering Harvard University, 309 Pierce Hall, Cambridge, Mass.

1900. *JOHNSON, WALLACE C. Consulting Engineer, Niagara Falls, N. Y.

1904. JOHNSON, W. MARTIN. Vice-President, The Schoen Steel Wheel Company, 1119 Frick Building, Pittsburg, Pa.

1905. *JONES, C. R. Professor of Mechanical Engineering, West Virginia University, Morgantown, W. Va.

1902. *†JONES AND LAUGHLIN STEEL COMPANY. Steel Manufacturers; Willis L. King, Vice-President, Pittsburg, Pa.

1903. JORDAN, WILLIAM, JR. 1642 South Broad Street, Philadelphia, Pa.

1904. KAHN, MORITZ. Resident Representative, Trussed Concrete Steel Company, 160 Fifth Avenue, New York, N. Y

1904. KASSON, HENRY R. District Manager, Barber Asphalt Paving Company, 1236 Stock Exchange Building, Chicago, Ill.

1904. *KAY, EDGAR B. Professor of Engineering, University of Alabama, University Post Office, Ala.

1903. KEAY, H. O. Chief Draughtsman, Motive Power Department, Boston and Maine Railroad, Boston, Mass.

1896. *KEEP, WILLIAM J. Superintendent, Michigan Stove Company, 753 Jefferson Avenue, Detroit, Mich.

1899. KENNEDY, FRANK G., JR. Superintendent, Logan Iron and Steel Company, Burnham, Mifflin County, Pa.

1904. *KENNEDY, JEREMIAH J. Consulting Engineer, 52 Broadway, New York, N. Y.

1899. *KENNEDY, JULIAN. Consulting Engineer, Latrobe Steel Company, Pittsburg, Pa.

1904. KENNEY, E. F. Engineer of Tests, Pennsylvania Railroad Company, Broad Street Station, Philadelphia, Pa.

1902. KENT, WILLIAM. Professor of Mechanical Engineering, and Dean of the L. C. Smith College of Applied Science Syracuse University, Syracuse, N. Y.

ELECTED.

1904. KENYON, CLARENCE A. President, Hoosier Construction Company and Granite Bituminous Paving Company Indianapolis, Ind.

1904. KENYON, E. H., Inspector Engineer, 421 Wond Street, Pittsburg, Pa.

1905. KETCHUM, MILO S. Professor of Civil Engineering, University of Colorado, Boulder, Col.

1903. *KIESEL, W. F., JR. Assistant Mechanical Engineer, Pennsylvania Railroad, Altoona, Pa.

1905. KING, W. GRANT. Manager, Iroquois Iron Works, 178 Walden Avenue, Buffalo, N. Y.

1899. *KING, WILLIS L. Vice-President, Jones and Laughlin Steel Company, Pittsburg, Pa.

1899. *KINKEAD, J. A. Engineer of Tests, American Locomotive Company, Schenectady, N. Y.

1902. *KIRCHHOFF, C. Editor, *The Iron Age*, 232 William Street, New York, N. Y.

1903. KIRCHNER, PAUL A. Engineer of Bridges, New York, West Chester and Boston Railway Company, 30 Broad Street, New York, N. Y.

1903. *KITTREDGE, H. G. Secretary, The Kay and Ess Company, Dayton, O.

1905. KLINGER, P. W. Assistant Superintendent, Barney and Smith Car Company, 236 Crafton Avenue, Dayton, O.

1905. KNAPP, H. C. Manager, Railway Department, Parrott Varnish Company, 150 Nassau Street, New York, N. Y.

1904. KNIGHT, FRANK B. Engineer, Lidgerwood Manufacturing Company, 96 Liberty Street, New York, N. Y.

1903. KNIGHTON, J. A. Assistant Engineer, Bridge Department, Park Row Building, New York, N. Y.

1904. KNOWLES, MORRIS. Chief Engineer, Bureau of Filtration Pittsburg, Pa.

1903. KOHR, D. A. Chemist, Lowe Brothers, Dayton, O.

1896. *KREUZPOINTNER, PAUL. Pennsylvania Railroad, Altoona, Pa

1904. KRUPP COMPANY, Fried.; Emil Ehrensberger, Director Essen, Germany.

1904. KUMMER, FREDERIC A. General Manager, United States Wood Preserving Company, 29 Broadway, New York N. Y.

ELECTED.

1903. LA CHICOTTE, H. A. Engineer in Charge, Manhattan Bridge (No. 3) and Blackwell's Island Bridge (No. 4), Park Row Building, New York, N. Y.

1905. *LACKAWANNA STEEL COMPANY. Franklin E. Abbott, Inspecting Engineer, Buffalo, N. Y.

1903. *LANE, HENRY M. Editor, *The Foundry*, Browning Building, Cleveland, O. *For Mail:* 123 Robinwood Avenue, Lakewood, O.

1905. LANGTON, W. A. Editor, *Canadian Architect*, Confederation Life Building, Toronto, Canada.

1899. *LANZA, GAETANO. Professor Theoretical and Applied Mechanics, in charge Mechanical Engineering Department, Massachusetts Institute of Technology, Boston, Mass.

1904. LARNED, E. S. Manager, United Building Materials Company, 101 Milk Street, Boston, Mass.

1903. LARSSON, C. G. E. Assistant Chief Engineer, American Bridge Company, Ambridge, Pa.

1898. *†LATROBE STEEL COMPANY. Marriott C. Smyth, President, 1200 Girard Building, Philadelphia, Pa.

1903. LAYMAN, W. A. General Manager, Wagner Electrical Manufacturing Company, 2017 Locust Street, St. Louis, Mo.

1904. LEIGHTON, MARSHALL O. Chief, Division of Hydro-Economics, United States Geological Survey, Washington, D. C.

1904. LEMEN, W. W. Engineer of Tests, Norfolk and Western Railway, Roanoke, Va.

1903. LEMOINE, L. R. Resident Manager, United States Cast-Iron Pipe and Foundry Company, Land Title Building, Philadelphia, Pa.

1898. *†LESLEY, R. W. (*Vice-President*). President, American Cement Company, Pennsylvania Building, Philadelphia, Pa.

1903. LEWIS, FREDERICK H. Consulting Engineer, Echoll's Building, Staunton, Va.

1905. LEWIS, JOHN F. Chief Inspector, Duquesne Steel Works, Carnegie Steel Company, Duquesne, Pa.

1904. LEWIS, NELSON P. Chief Engineer, Board of Estimate and Apportionment, 277 Broadway, New York, N. Y.

1904. *LIDGERWOOD, JOHN H., JR. Engineer, Lidgerwood Manufacturing Company, 96 Liberty Street, New York, N. Y.

ELECTED.

1905. *LIMA LOCOMOTIVE AND MACHINE COMPANY, THE. W. H. Agerter, Secretary and Treasurer, Lima, O.

1896. LINDENTHAL, GUSTAV. Consulting Engineer, 45 Cedar Street, New York, N. Y.

1902. LINTON, HARVEY. City Engineer, Altoona, Pa.

1903. *LITTLE, A. D. Chemical Expert and Engineer, 93 Broad Street, Boston Mass.

1905. LLOYD, JOHN. Banker and Coal Operator, Altoona, Pa.

1903. *LOBDELL, W. W. President, Lobdell Car-Wheel Company, Wilmington, Del.

1902. LOBER, J. B. Vice-President, Vulcanite Portland Cement Company, Land Title Building, Philadelphia, Pa.

1904. LOBER, W. H. Inspector General, Barber Asphalt Paving Company, Rialto Building, San Francisco, Cal.

1905. *LOHMANN, H. W. Manager, James Stewart and Company, Engineers and Contractors, 302 Lincoln Trust Building, St. Louis, Mo.

1905. LONG, E. MCLEAN. Civil Engineer, Inspector of Steel, 220 Broadway, New York, N. Y.

1904. *LONG, R. A. President and General Manager, The Long-Bell Lumber Company, Keith and Perry Building, Kansas City, Mo.

1904. LONG, WILLIAM. Engineer of Tests, Bureau of Engraving and Printing, 2133 K Street, N., Washington, D. C.

1904. LOOMIS, HENRY M. Chemist, Box 185, Harrisburg, Pa.

1904. LORD, E. C. E. Petographer, United StatesDepartment of Agriculture, Washington, D. C.

1903. LORDLY, HENRY ROBERTSON. Engineer in Charge, Lachine Canal, Royal Insurance Building, Montreal, Canada.

1904. LOUDENBECK, H. C. Chemist and Metallurgist, Westinghouse Air Brake Company, Wilmerding, Pa.

1903. LOUDON, ARCH. M. Foundryman, Elmira, N. Y.

1902. LOVELL, EARL B. Adjunct Professor of Civil Engineering, Columbia University, 235 West One Hundred and Second Street, New York, N. Y.

1899. LOWE BROTHERS. Paint and Color Makers; Houston Lowe, Vice-President, Dayton, O.

1900. LOWETH, CHARLES F. Engineer and Superintendent of Bridges and Buildings, Chicago, Milwaukee and St. Paul Railway, 1232 Railway Exchange, Chicago, Ill.

1905. LUCAS AND COMPANY. John W. Irving Lewis, Consulting and Contracting Representative, 322--330 Race Street, Philadelphia.

ELECTED.

1904. LUDLOW, S. H. Chemist, National Portland Cement Company, Durham, Ontario, Canada.

1905. LUKENS, ALAN N. Mechanical Engineer, Railway Steel Spring Company, 71 Broadway, New York, N. Y.

1902. †LUKENS IRON AND STEEL COMPANY. Charles L. Huston, Vice-President, Coatesville, Pa.

1898. LUNDTEIGEN, ANDREAS. Chemist, Union City, Mich.

1902. LYNCH, T. D. Engineer of Material Tests, Westinghouse Electric and Manufacturing Company, East Pittsburg, Pa.

1902. MACPHERRAN, R S. Chemist, Allis-Chalmers Company, Milwaukee, Wis.

1905. MCCAFFERY, RICHARD S. General Manager, Glamorgan Pipe and Foundry Company, Lynchburg, Va.

1905. MCCASKEY, H. D. Chief of the Mining Bureau, Department of Interior, Box 449, Manila, P. I.

1896. MCCAULEY, H. K. Secretary and Treasurer, Altoona Iron Company, Altoona, Pa.

1905. MCCREA, ARCHIBALD M. President, Union Spring and Manufacturing Company, Farmers' Bank Building, Pittsburg, Pa.

1903. *MCCREADY, ERNEST B. General Manager Lehigh Valley Testing Laboratory, Fourth and Linden Streets, Allentown, Pa.

1905. MCGRADY, J. W. Chief Inspector, Homestead Steel Works, Carnegie Steel Company, Munhall, Pa.

1896. *MCKENNA, CHARLES F. Chemist, 221 Pearl Street, New York, N. Y.

1905. MCKIBBEN, FRANK P. Assistant Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.

1904. MCLEAN, E. Foreman, Wheel Foundry, Pennsylvania Railroad, Altoona, Pa.

1902. *†MCLEOD, JOHN (*Member of Executive Committee*). 1108 Pennsylvania Building, Philadelphia, Pa.

1904. *MCNAUGHER, D. W. Civil Engineer, Monongahela Bank Building, Pittsburg, Pa.

1903. MCQUEEN, J. W. Secretary, Sloss-Sheffield Iron and Steel Company, Birmingham, Ala.

1904. *MACK, J. LATHROP. Chemist, Nazareth Cement Company, Nazareth, Pa.

ELECTED.

1895. *MACLAY, WILLIAM W. President, Glens Falls Portland Cement Company, Glens Falls, N. Y.

1904. MAHON, R. W. Chemist, New York Central and Hudson River Railroad, West Albany, N. Y.

1902. MAJOR, CHARLES. President, A. and P. Roberts Company; Manager, Pencoyd Iron Works, Pencoyd, Pa.

1898. *MARBURG, EDGAR (*Secretary-Treasurer*). Professor of Civil Engineering, University of Pennsylvania, Philadelphia, Pa.

1905. *MARQUETTE CEMENT MANUFACTURING COMPANY. T. G. Dickinson, General Manager, La Salle, Ill.

1905. MARSTEN, A. Dean of Division of Engineering, Iowa State College, Ames, Iowa.

1903. MARTIN, HENRY G. Metallurgist, Lukens Iron and Steel Company, P. O. Box 478, Coatesville, Pa.

1902. MARTIN, SIMON S. Superintendent, Maryland Steel Company, Sparrows Point, Md.

1903. MASTERS, J. B. Inspecting Engineer, Pittsburg Representative of Hildreth and Company, 506 North St. Clair Street, Pittsburg, Pa.

1902. MATCHAM, CHARLES A. Manager, Lehigh Portland Cement Company, Allentown, Pa.

1903. MATHEWS, JOHN A. Assistant Engineer, Sanderson Works, Crucible Steel Company of America, Syracuse, N. Y.

1904. *MAURER, E. R. Professor of Mechanics, University of Wisconsin, Madison, Wis.

1904. MEAD, CHARLES ADRIANCE. Principal Assistant to Boller and Hodge, Engineers, New York, N. Y., 165 Wildwood Avenue, Upper Montclair, N. J.

1899. MEADE RICHARD K. Chemist, Dexter Portland Cement Company, Nazareth, Pa.

1905. MEANS, E. C. General Manager, The Low Moor Iron Company of Virginia, Low Moor, Va.

1902. MEIER, E. D. President and Chief Engineer, Herne Safety Boiler Company, 11 Broadway, New York, N. Y.

1905. MERRILL, JR., W. H. Secretary, Underwriters' Laboratories, 382 Ohio Street, Chicago, Ill.

1895. *MERRIMAN, MANSFIELD (*Past-President*). Professor of Civil Engineering, Lehigh University, South Bethlehem, Pa.

1903. METCALF, WILLIAM. Braeburn Steel Company, Braeburn, Pa.

1904. MILLAR W. G. A. Purchasing Agent, American Bridge Company, 30 Orchard Avenue, Bellevue, Pa.

ELECTED.

1905. MILLER, H. C. Specialist in Steel Concrete Construction, 1 Madison Avenue, New York, N. Y.

1903. MILLER, JOHN S., JR. Assistant Chemist, Supervising Architect's Office, Treasury Department, Washington, D. C.

1903. MILLER, RUDOLPH P. Chief Engineer, Bureau of Buildings, 141 East Fortieth Street, New York, N. Y.

1900. MILLS, CHARLES M. Principal Assistant Engineer, Subway and Elevated Railroad Construction, Philadelphia Rapid Transit Company, Philadelphia, Pa.

1903. MITCHELL, ARTHUR M. Secretary, The Eureka Chemical Company, 5 Howard Street, Newark, N. J.

1904. *MITCHELL, A. S. Analytical Chemist, 220 Greenbush Street, Milwaukee, Wis.

1903. †MITCHELL, JOSEPH. With John Williams Bronze and Iron Works, 556 West Twenty-seventh Street, New York City, N. Y.

1901. MITCHELL, WILLIAM tH. 519 Arch Street, Philadelphia, Pa.

1904. MIX, CHARLES DORF. Steel Merchant, 102 Purchase Street, Boston, Mass.

1905. MOECHEL, J. ROBT. Kansas City Chemic-Technic Laboratories, Eighth and Locust Streets, Kansas City, Mo.

1903. *MOISSEFF, LEON S. Assistant Engineer to Commissioner of Bridges, 13 Park Row, New York City, N. Y.

1896. *MOLDENKE, RICHARD. Metallurgist, Consulting Engineer, Watchung, N. J.

1903. MOORE, HERBERT F. Instructor in Testing Laboratory, University of Wisconsin, 919 University Avenue, Madison, Wis.

1905. MOORE, JOHN E. In Charge of Chemical and Cement Laboratories, Robert W. Hunt and Company, 1122 Rookery, Chicago, Ill.

1905. MOORE, LEE C. Consulting Mechanical Engineer, 908 House Building, Pittsburg, Pa.

1902. *MOORE, WILLIAM HARLEY. Engineer of Bridges, New York, New Haven and Hartford Railroad, New Haven, Conn.

1905. MORGAN CONSTRUCTION COMPANY. Victor E. Edwards, Mechanical Engineer, Worcester, Mass.

1905. *MORRISON, HUGH S. Mechanical Engineer, Mutual Assurance Society Building, Richmond, Va.

ELECTED.

1905. MORROW, JAY J. Captain, Corps of Engineers, United States Army, Assistant to Engineers Commissioner, District of Columbia, District Building, Washington, D. C.

1905. MORSE, EDWIN KIRTLAND. Civil Engineer, Pittsburg, Pa.

1904. MOSELEY, ALEX. W. Professor of Applied Mechanics, Lewis Institute, Chicago, Ill.

1904. †MUDGE, H. U. Second Vice-President, Chicago, Rock Island and Pacific Railway Company, La Salle Street Station, Chicago, Ill.

1899. *MUESER, WILLIAM. Civil Engineer; Member, Concrete Steel Engineering Company, 13-21 Park Row Building, New York, N. Y.

1903. MUNROE, CHARLES EDWARD. Head Professor of Chemistry, George Washington University, Washington, D. C.

1904. MUNSELL, A. W. Cement Inspector, Baltimore and Ohio Railroad, Twenty-first and Water Streets, Wheeling, W. Va.

1899. *MUTUAL BOILER INSURANCE COMPANY. 31 Milk Street, Boston, Mass.

1905. *MYERS, JR., E. T. D. Civil Engineer, Mutual Assurance Society Building, Richmond, Va.

1904. NAEGELEY, JOHN C. Engineer and Architect, 184 Richmond Avenue, Buffalo, N. Y.

1905. NATIONAL FIRE PROOFING COMPANY. E. V. Johnson, Vice-President and Western Manager, 806 Hartford Building, Chicago, Ill.

1900. NATIONAL TUBE COMPANY. Frank N. Speller, Metallurgical Engineer, Frick Building, Pittsburg, Pa.

1902. NEFF, F. H. Professor of Civil Engineering, Case School of Applied Science, Cleveland, O.

1904. NEILSON, GEORGE HARRISON. General Manager, Braeburn Steel Company, Braeburn, Pa.

1904. *NELSON, E. D. Engineer of Tests, Pennsylvania Railroad Company, Altoona, Pa.

1902. NEW YORK AIR BRAKE COMPANY, THE. R. C. Augur, Mechanical Engineer, Watertown, N. Y.

1904. NEW YORK FIRE INSURANCE EXCHANGE. Henry E. Hess, Manager, 32 Nassau Street, New York, N. Y.

1898. *NEWBERRY, SPENCER B. Manager, Sandusky Portland Cement Company, Sandusky, O.

1905. NEWELL, F. H. Chief Engineer, United States Reclamation Service, 1330 F Street, Washington, D. C.

ELECTED.

1902. NORRIS, GEORGE L. Chemist, Standard Steel Works, Burnham, Pa.

1903. NORTON, C. L. Assistant Professor of Heat Measurement, Massachusetts Institute of Technology, Boston, Mass.

1904. NORTON, F. LEE. General Manager, J. I. Case Threshing Machine Company, Racine, Wis.

1905. NORTH, A. T. Chief Engineer, Western Department, National Fire Proofing Company, 806 Hartford Building, Chicago, Ill.

1898. OLSEN, TINIUS. Tinius Olsen and Company, Testing Machines, 500 North Twelfth Street, Philadelphia, Pa.

1902. ONDERDONK, J. R. Engineer of Tests, Baltimore and Ohio Railroad, Mt. Clare, Baltimore, Md.

1903. †ORFORD COPPER COMPANY. 43 Exchange Place, New York, N. Y.

1902. ORTON, EDWARD, JR. Dean, College of Engineering, Ohio State University, and State Geologist of Ohio, Columbus, O.

1898. OSBORN ENGINEERING COMPANY, THE. Frank C. Osborn, Cleveland, O.

1903. *OSTROM, JOHN N. Bridge Engineer, 1518 Farmers' Bank Building, Pittsburg, Pa.

1904. *OTIS, SPENCER. Mechanical Engineer, 1707 Railway Exchange Building, Chicago, Ill.

1902. OUTERBRIDGE, ALEX. E., JR. Chemist and Metallurgist, 1600 Hamilton Street, Philadelphia, Pa.

1904. *OWEN, JAMES. Civil Engineer, 196 Market Street, Newark, N. J.

1903. PAGE, LOGAN WALLER. Chief of Road Material Laboratory, United States Department of Agriculture, Washington, D. C.

1903. PARK, LOUIS L. Chief Draughtsman, Rogers Locomotive Works, Paterson, N. J.

1904. PEARSON, HENRY. Vice-President and General Manager, Wason Manufacturing Company, Brightwood, Mass.

1896. PEASE, F. N. Assistant Chemist, Pennsylvania Railroad, 345 East Thirty-third Street, New York, N. Y.

1903. PECKHAM, S. F. Chemist to the Commissioners of Accounts, New York City, Room 104, 280 Broadway, New York, N. Y.

ELECTED.

1903. PECKITT, LEONARD. President, Empire Steel and Iron Company, Catasauqua, Pa.

1904. PEEBLES, JOHN. Factory Superintendent, J. I. Case Threshing Machine Company, 712 Lake Avenue, Racine Wis.

1902. †PENNSYLVANIA STEEL COMPANY, THE. H. H. Campbell Superintendent and General Manager, Steelton, Pa.

1904. PERLEY, GEORGE E. Cement Expert, Department of Public Works, Ottawa, Canada.

1905. PETERS, J. M. Manager, White Lead Department, W. J. Mathews and Company, Limited, 200 Water Street, New York, N. Y.

1905. *PEW, J. HOWARD. Assistant Manager, Refinery, Sun Company, Marcus Hook, Pa.

1903 PHILLIPS, WILLIAM BATTLE. Mining Engineer and Metallurgist; Director, University of Texas Mineral Survey, Austin, Tex.

1905. PHLEGAR, A. A., JR. Chemist, Norfolk and Western Railway, Roanoke, Va.

1905. PICKANDS-MAGEE COKE COMPANY. W. C. Magee, President, Frick Building, Pittsburg, Pa.

1903 *PINCHOT, GIFFORD. Forester, United States Department of Agriculture, Washington, D. C.

1904. *PITTSBURG FORGE AND IRON COMPANY. F. E. Richardson, Secretary, Pittsburg, Pa.

1905. *PITTSBURG TESTING LABORATORY, LIMITED. John M. Bailey, Secretary, 325 Water Street, Pittsburg, Pa.

1905. PLATT, J. C. Engineer of Tests, Erie Railroad Company, Meadville, Pa.

1902. *†POLK, W. A. Sales Agent, The Patterson-Sargent Company, 42 Hudson Street, New York, N. Y.

1904. *POMEROY, LEWIS R. Special Representative, Railway Department, General Electric Company, 44 Broad Street, New York, N. Y.

1898. PORTER, JAMES MADISON. Professor of Civil Engineering, Lafayette College, Easton, Pa.

1905. POWELL, E. B. Chemist, The New York Edison Company, 1064 Madison Avenue, New York, N. Y.

1903. POWELL, H. S. Sanitary Engineer, 327 Bond Street, Washington, D. C.

1904. POWELL, J. E. Chief Mechanical and Electrical Engineer, Office of Supervising Architect, Treasury Department, Washington, D. C.

ELECTED.

1903. POWERS, W. A. Chief Chemist, Atchison, Topeka and Santa Fé Railroad, Topeka, Kan.

1904. PRENTISS, GEORGE N. Chemist, Chicago, Milwaukee and St. Paul Railway, 2910 Clybourn Street, Milwaukee, Wis.

1904. PRESTON, S. R. Superintendent, Virginia Portland Cement Company, Fordwick, Augusta County, Va.

1903. PRICE, MORTON MOORE. Civil Engineer, Babcock and Wil cox Company, Bayonne, N. J.

1905 PRINCE, C. L. Manager Foundry Office, General Electric Company, Schenectady, N. Y.

1904. PRINCE, J. W. Mechanical Engineer, Vineland, N. J.

1905. PROVOST, ANDREW J., JR. Engineer to Commissioner of Public Works, Borough Hall, Brooklyn, N. Y.

1904. PURDON, C. D. Engineer, Maintenance of Way, Frisco System, Frisco Building, St. Louis, Mo.

1905. *QUICK, CHARLES DELAVAN. Assistant Superintendent, Iranton Portland Cement Company, 187 Park Avenue, Iranton, Ohio.

1904. QUIMBY, CHARLES H. Assistant Engineer, Yards and Buildings, American Bridge Company, 115 Rochelle Avenue, Wissahickon, Philadelphia, Pa.

1903. QUIMBY, H. H. Assistant Engineer of Bridges, Bureau of Surveys, 863 North Twenty-third Street, Philadelphia, Pa.

1898. RAILROAD GAZETTE. W. H. Boardman, Editor, 83 Fulton Street, New York, N. Y.

1902. RAILWAY AND ENGINEERING REVIEW. W. M. Camp, Editor, 1305 Manhattan Building, Chicago, Ill.

1904. RAMAGE, J. C. Superintendent of Tests, Southern Railway Company, Alexandria, Va.

1904. *RAMSAY, H. MARTYN. General Inspector, Pennsylvania Railroad Company, Altoona, Pa.

1896. *RANDOLPH, LINGAN S. Professor of Mechanical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

1905. READ, C. P. Assistant Engineer, Interborough Rapid Transit Company, 75 East Fifty-Fourth Street, New York, N. Y.

1902. READING IRON COMPANY. Reading, Pa.

1905. REBER, LOUIS E. Dean, School of Engineering, The Pennsylvania State College, State College, Pa.

ELECTED.

1904. REEVE, C. S. Chemist, Philadelphia Municipal Testing Laboratories, 318 City Hall, Philadelphia, Pa.

1902. REID, DAVID. General Foreman, Foundry Department, Canadian Westinghouse Company Limited, 253 Wentworth Street, Hamilton, Canada.

1905. REYNOLDS, J. C. Assistant Engineer, Rapid Transit Railroad Commission, 2041 Washington Avenue, New York, N. Y.

1898. RICE, FRANCIS S. Structural Engineer, Aspinwall, Pa.

1900. RICHARDS, JOSEPH T. Chief Engineer, Maintenance of Way, Pennsylvania Railroad, Broad Street Station, Philadelphia, Pa.

1902. *RICHARDS, JOSEPH W. Assistant Professor of Metallurgy, Lehigh University, South Bethlehem, Pa.

1902. RICHARDS, ROBERT H. Professor of Mining Engineering and Metallurgy, Massachusetts Institute of Technology, Boston, Mass.

1904. *RICHARDS, W. D. Houghton and Richards, 150 Oliver Street, Boston, Mass.

1896. *RICHARDSON, CLIFFORD. Asphalt Expert, New York Testing Laboratory, Long Island City, N. Y.

1903. RICHARDSON, WILLARD D. Ceramic Engineer, Columbus, O.

1900. RICHTER, A. W. Professor of Experimental Engineering, University of Wisconsin, 929 University Avenue, Madison, Wis.

1902. RIEGNER, W. B. Engineer of Bridges, Philadelphia and Reading Railway, Reading Terminal, Philadelphia.

1898. *RIEHLE, FREDERICK A. Riehlé Brothers Testing Machine Company, 1424 North Ninth Street, Philadelphia, Pa.

1904. *ROBERTS, ALFRED E. Analytical and Consulting Chemist and Metallurgist, Bull and Roberts, 100 Maiden Lane New York, N. Y.

1904. ROBERTSON, LESLIE S. Secretary of the Engineering Standards Committee, 28 Victoria Street, London, England.

1904. ROBINSON, A. F. Bridge Engineer, Atchison, Topeka and Santa Fé Railroad, 1000 Railway Exchange Building, Chicago, Ill.

1905. *ROBINSON, HOLTON D. Engineer in Charge of Manhattan Bridge, 21 Park Row, New York, N. Y.

1903. ROBINSON, JOHN C. 52 Pearl Street, Springfield, Mass.

ELECTED.

1904. ROCK PRODUCTS. S. V. Peppel, Technical Editor, 431 West Main Street, Louisville, Ky.

1900. *ROEBLING'S SONS COMPANY, JOHN A. H. J. Horne, Assistant Superintendent, Department of Wiredrawing, Trenton, N. J.

1904. ROEPPER, C. W. Metallurgical Engineer, Mount Airy Station, Philadelphia, Pa.

1905. *ROSENHEIM, A. F. Architect, H. W. Hellman Building, Los Angeles, Cal.

1905. *ROSSI, JAMES J. General Superintendent, National Fire Proofing Company, 71 Lewis Street, Perth Amboy, N. J.

1903. ROYAL, JOSEPH. Inspecting Engineer, P. O. Box 174, Rutledge, Pa.

1904. RUTHENBURG, MARCUS. Electro-Metallurgical Engineer, Lockport, N. Y.

1898. SABIN, A. H. Chemist, 432 Sanford Avenue, New York, N. Y.

1902. SABIN, L. C. Secretary, American Section, International Waterways Commission, 328 Federal Building, Buffalo, N. Y.

1905. SAFFORD, H. R. Assistant Chief Engineer, Illinois Central Railroad, Chicago, Ill.

1902 SAGUE, J. E. Vice-President, American Locomotive Company, 25 Broad Street, New York, N. Y.

1904. SALMON, FREDERICK W. Civil and Mechanical Engineer 127 South Central Avenue, Burlington, Iowa.

1905. SANGUINET, M. R. Architect, Home Building, Fort Worth, Tex.

1904. SAUNDERS, GEORGE C. Manager, Eastern District, The Osborn Engineering Company, 1122 Land Title Building Philadelphia, Pa.

1902. SAUNDERS, WALTER M. Analytical and Consulting Chemist, 184 Whittier Avenue, Providence, R. I.

1896. *SAUVEUR, ALBERT. Assistant Professor of Metallurgy, Harvard University; Manager, Boston Testing Laboratories, Rotch Building, Harvard University, Cambridge, Mass.

1903. SCARBOROUGH, F. W. Mining Engineer, Macdonald, W. Va.

1904. SCHADE, G. C. 297 Main Street, Arsenal Station, Pittsburg, Pa.

ELECTED.

1898. SCHAFFER, HERBERT A. Chief Chemist, The Northampton and Quaker Portland Cement Company, 321 Spring Garden Street, Easton, Pa.

1904. SCHENK, PIERCE D. Vice-President and Assistant General Manager, The Dayton Malleable Iron Company, Dayton, O.

1904. SCHMITT, F. E. Associate Editor, *The Engineering News* 220 Broadway, New York, N. Y.

1905. SCHNEIDER, C. C. Consulting Engineer, Pennsylvania Building, Philadelphia, Pa.

1900. SCHNEIDER, HERMAN. Professor of Civil Engineering, University of Cincinnati, Cincinnati, O.

1905. *SCHNIEWIND, F. Consulting Chemical Engineer; Vice-President, The United Coke and Gas Company, 17 Battery Place, New York, N. Y.

1903. SCHROEDER, C. M. Chemist, 221 Pearl Street, New York, N. Y.

1902. SCHUERMAN, W. H. Dean of Engineering Department and Professor of Civil Engineering, Vanderbilt University, Nashville, Tenn.

1905. SCHWARTZ, ARCHIE W. Inspector, Bureau of Buildings, Borough of Manhattan, 65 West Eleventh Street, New York, N. Y.

1904. *SCOTT, WILLIAM F. Dunnville, Ontario, Canada.

1902. *SCOTT, W. G. Chemist, J. I. Case Threshing Machine Company, 1109 Park Avenue, Racine, Wis.

1905. SCRIBNER, C. E. Chief Engineer, Western Electric Company, 463 West Street, New York, N. Y.

1898. SEAMAN, HARRY J. Superintendent, Atlas Cement Company, Catasauqua, Pa.

1902. SEAMAN, HENRY B. Civil Engineer, 40 Wall Street, New York, N. Y.

1904. *SELLERS AND COMPANY, WILLIAM. Coleman Sellers, President, 1600 Hamilton Street, Philadelphia, Pa.

1902. *SHANKLAND, E. C. AND R. M. Civil Engineers, 1106 Rookery, Chicago, Ill.

1903. SHEAFF, J. C. Manager, Patterson-Sargent Company, 42 Hudson Street, New York, N. Y.

1902. *SHELBY STEEL TUBE COMPANY. J. H. Nicholson, Assistant to First Vice-President, Frick Building, Pittsburg, Pa.

1903. SHERMAN, C. W. General Manager, Pennsylvania Malleable Company, Central Car Wheel Company, Frick Building, Pittsburg, Pa.

ELECTED.

1904. SHERMAN, HERBERT L. Analytical Chemist, 220 Devonshire Street, Boston, Mass.

1903. SHERRERD, MORRIS R. Engineer and Superintendent, Department of Water, City of Newark, 128 Halsey Street, Newark, N. J.

1902. SHERWIN-WILLIAMS COMPANY, THE. Paint and Varnish Makers, E. C. Holton, Chemist in Chief, 100 Canal Street, Cleveland, O.

1899. *SHIMER, PORTER W. Chemist and Metallurgist, Easton, Pa.

1902. SHUMAN, JESSE J. Chief Inspector, Testing Department, Jones and Laughlin Steel Company, Pittsburg, Pa.

1904. SIMMONS, WILLIAM H. Chief Chemist, Detroit Portland Cement Company, Fenton, Mich.

1904. SIMPSON BROTHERS CORPORATION. 166 Devonshire Street, Boston, Mass.

1903. *SKINNER, C. E. Electrical Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburg, Pa.

1904. *SKINNER, ORVILLE CAMPBELL. Superintendent, Open-Hearth Department, Standard Steel Works, P. O. Box 165, Burnham, Pa.

1905. SLOAN, MAURICE M. Structural Engineer, Ballinger and Perrot, 1200 Chestnut Street, Philadelphia, Pa.

1903. *SLOCUM, A. W. General Superintendent, Keystone Car Wheel Company, 5500 Irwin Ave., Pittsburg, Pa.

1902. SMITH, H. E. Chemist, The Lake Shore and Michigan Southern Railway Company, Collinwood, O.

1905. SMITH, JAMES CRUICKSHANK. Chemical Engineer and Color Trade Expert, 5 The Elms, London Road, Wembley, Middlesex, England.

1904. SNODGRASS, A. E. Portland Cement Department, Louisville Cement Company, Sellersburg, Ind.

1902. *SNOW, J. P. Bridge Engineer, Boston and Maine Railroad, Boston, Mass. *For Mail*, 58 Chandler Street, West Somerville, Mass.

1905. *SNOW, WALTER B. Manager, Advance Department, B. F. Sturtevant Company, Hyde Park, Mass.

1904. *SOLVAY PROCESS COMPANY, THE. George B. Hartley, Chief Inspector, Syracuse, N. Y.

1904. *SOMERVILLE, C. W. Computer in charge of Tests, Building Department, Washington, D. C.

1904. SOULE, R. H. Consulting Engineer, 1571 Beacon Street, Brookline, Mass.

ELECTED.

1903. *SOUTHER, HENRY. Consulting Metallurgical Engineer, State Chemist, 440 Capitol Avenue, Hartford, Conn.

1904. SPACKMAN HENRY S., ENGINEERING COMPANY, 42 North Sixteenth Street, Philadelphia, Pa.

1905. SPALDING, F. P. Professor of Civil Engineering, University of Missouri, Columbia, Mo.

1902. SPANGLER, H. W. Professor of Mechanical Engineering, University of Pennsylvania, Philadelphia, Pa.

1905. SPARE, C. R. Chemist, Wm. Cramp and Sons Ship and Engine Building Company, Beach and Ball Streets, Philadelphia, Pa.

1901. SPERRY, W. L. Superintendent and Manager, The Cumberland Hydraulic Cement and Manufacturing Company, P. O. Box 264, Cumberland, Md.

1902. *STANDARD STEEL WORKS. A. A. Stevenson, Assistant Superintendent, Burnham, Pa.

1905. *STANGER, R. H. HARRY. Consulting Engineer, Testing Works and Chemical Laboratories, 2 Broadway, Westminster, London, S. W. England.

1903. *STAPLETON, F. M. Inspector, Chicago and Northwestern Railway, 504 Smithfield Street, Pittsburg, Pa.

1904. *STATTELMANN, G. R. 37 West Washington Street, Dayton, Ohio.

1896. STAUFFER, DAVID McN. Civil Engineer; Editor, *Engineering News*, 220 Broadway, New York, N. Y.

1899. *STEINMAN, A. J. Chairman, Pennsylvania Iron Company, Limited, Lancaster, Pa.

1905. STEVENS, HILDING A. Salesman, Toch Brothers, 25 West Twenty-fourth Street, New York, N. Y.

1896. *STEVENSON, A. A. Assistant Superintendent, Standard Steel Works, Burnham, Mifflin County, Pa.

1903. *STEWART, CLINTON R. Engineer of Tests, Cambria Steel Company, Johnstown, Pa.

1004. STEWART, P. M. Consulting Engineer, The Nevada, Broadway and Seventieth Street, New York, N. Y.

1899. *STILLMAN, THOMAS B. Professor of Chemistry, Stevens Institute of Technology, Hoboken, N. J.

1903. STOREY, W. B., JR. Chief Engineer, Atchison, Topeka and Santa Fé Railroad Company, Topeka, Kan.

1904. STORMER, EDW. J. Chemist, J. I. Case Plow Works, Racine, Wis.

ELECTED.

1602. *STOUGHTON, BRADLEY. Adjunct Professor of Metallurgy and Consulting Metallurgist, Columbia University, New York, N. Y.

1903. STRATTON, E. PLATT. Chief Engineer Surveyor, American Bureau of Shipping, 66–70 Beaver Street, New York, N. Y.

1903. STREETER, LAFAYETTE P. Air Brake Inspector, Southern Pacific Company, *For Mail:* Post Office Box 1345, Los Angeles, Cal.

1896. STROBEL, CHARLES L. Consulting Engineer, 1744 Monadnock Block, Chicago, Ill.

1904. *STUETZ, E. Vice-President and Treasurer, The Goldschmidt Thermit Company, 43 Exchange Place, New York, N. Y.

1896. *SWAIN, GEORGE F. Professor of Civil Engineering, Massachusetts Institute of Technology, Boston, Mass.

1903. *SWANBERG, F. L. Secretary, The D. T. Williams Valve Company, 904–910 Broadway, Cincinnati, O.

1905. *SWARTZ, PAUL DAVIES. Cement Inspector, 75 Canal Street, Boston, Mass.

1903. *SWENSSON, EMIL. Consulting Engineer, Frick Building, Pittsburg, Pa.

1904. SWING, S. WALTER. Assistant to Engineer of Tests, Lukens Iron and Steel Company, Coatesville, Pa.

1905. *TABER, GEORGE H. General Manager, Gulf Refining Company, Frick Building, Pittsburg, Pa.

1903. TAGGART, HOWARD. Engineer of Tests, Lukens Iron and Steel Company, P. O. Box 632, Coatesville, Pa.

1898. *TALBOT, ARTHUR N. Professor of Municipal and Sanitary Engineering, University of Illinois, Urbana, Ill.

1902. *TALBOT, HENRY P. Professor of Inorganic and Analytical Chemistry, Massachusetts Institute of Technology, Boston Mass.

1904. TASSIN, WIRT. Chemist; Assistant Curator, National Museum, Washington, D. C.

1904. TAUBENHEIM, ULRICH E. Manager, City Water Works, Archangel, Russia.

1900. TAYLOR, WILLIAM PURVES. Engineer in Charge, Testing Laboratory, 318 City Hall, Philadelphia, Pa.

1896. *TECHNISCHER VEREIN, NEW YORK. Carl Kaelble, Secretary, Room 705, 290 Broadway, New York, N. Y.

ELECTED.

1896. *TECHNISCHER VEREIN, PHILADELPHIA. 534 North Fourth Street, Philadelphia, Pa.

1896. *TECHNISCHER VEREIN, PITTSBURG. Gustav A. Stielrin, Secretary, 166 Robinson Street, Pittsburg, Pa.

1896. *TECHNISCHER VEREIN, WASHINGTON. Paul Bausch, Corresponding Secretary, 3418 Brown Street, N. W., Washington, D. C.

1902. THACHER, EDWIN. Consulting Engineer; Member, Concrete-Steel Engineering Company, Park Row Building, New York, N. Y.

1904. THAYER AND COMPANY, INCORPORATED. 1015 Tremont Building, Boston, Mass.

1900. THOMAS, DAVID. Logan Iron and Steel Company, Burnham, Pa.

1903. THOMPSON, GUSTAVE W. Chemist, National Lead Company, 129 York Street, Brooklyn, N. Y.

1905. *THOMPSON, HUGH L. Consulting Engineer, Waterbury, Conn.

1904. THOMPSON, SANFORD E. Civil Engineer, Newton Highlands, Mass.

1904. THOMSON, FRANK K. Superintendent of Construction, Quartermaster's Department, United States Army, 185 Middle Street, Portland, Me.

1905. TILDEN, C. J. Instructor in Civil Engineering, University of Michigan, 1002 Cornwell Place, Ann Arbor, Mich.

1904. TILLSON, GEO. W. Chief Engineer, Bureau of Highways, Borough of Brooklyn, Municipal Building, Brooklyn, N. Y.

1905. TOBELMANN, HENRY A. Chemist, United States Reclamation Service, Roosevelt, Ar.

1903. *TOCH, MAXIMILIAN. Paint Manufacturer, 468 West Broadway, New York, N. Y.

1903. TOMKINS, CALVIN. Manufacturer, 17 Battery Place, New York, N. Y.

1903. TOUCEDA, ENRIQUE. Chemist and Metallurgist, 51 State Street, Albany, N. Y.

1905. *TRIST, N. B. Assistant to Vice-President, The Schoen Steel Wheel Company, Arcade Building, Philadelphia, Pa.

1904. TROOIEN, O. N. Assistant in Mechanical Engineering, South Dakota Agricultural College, Brookings, So. Dak.

1902. *TURNEAURE, F. E. Dean of the College of Mechanics and Engineering, University of Wisconsin, Madison, Wis.

ELECTED.

1902. *UMSTEAD, C. H. Superintendent of Construction, United States Public Buildings, 422 Washington Trust Building, Washington, Pa.

1904. VAN CLEVE, A. H. Resident Engineer, The Niagara Falls Power Company, Niagara Falls, N. Y.

1903. VAN GUNDY, C. P. Chief Chemist, Baltimore and Ohio Railroad, Mont Clare, Baltimore, Md.

1902. *VAN ORNUM, J. L. Professor of Civil Engineering, Washington University, St. Louis, Mo.

1903. VANNIER, CHARLES H. Consulting Engineer, 76 Harvard Place, Buffalo, N. Y.

1905. VAUGHAN, F. S. General Manager, The Vaughan Paint Company, Cleveland, O.

1896. VOGT, A. S. Mechanical Engineer, Pennsylvania Railroad, Altoona, Pa.

1904. VON AMMON, S. Consulting Engineer, Oswaldestre House, Norfolk Street, Strand, London, W. C., England.

1903. VON SCHRENK, HERMANN. Pathologist, Bureau of Plant Industry, United States Department of Agriculture, Missouri Botanical Gardens, St. Louis, Mo.

1902. VOORHEES, S. S. Engineer of Tests, Treasury Department, Washington, D. C.

1903. *VREDENBURGH, WATSON, JR. Member, Hildreth and Company, Engineers, 50 Broadway, New York, N. Y.

1904. *WACHTER, CHARLES LUCAS. Assistant Engineer, Lidgerwood Manufacturing Company, 96 Liberty Street, New York, N. Y.

1896. *WADDELL, J. A. L. Consulting Civil Engineer, Kansas City, Mo.

1904. WAGENHORST, JAMES H. Westinghouse Machine Company, Pittsburg, Pa.

1899. *WAGNER, SAMUEL TOBIAS. Assistant Engineer, Philadelphia and Reading Railway, Reading Terminal, Philadelphia, Pa.

1903. WAID, D. EVERETT. Architect, 156 Fifth Avenue, New York, N. Y.

1904. WALDO BROS. 102 Milk Street, Boston, Mass.

1905. WALKER, I. O. Assistant Engineer, Nashville, Chattanooga and St. Louis Railway, Paducah and Memphis Division, 1231 South Sixth Street, Paducah, Ky.

ELECTED.

1902. *WALKER, JOSEPH F. Chemist, The Protectus Company, Bridgeport, Pa.

1903. WALKER, R. F. Cement Tester in Charge, Rapid Transit Railway, New York, 412 Turner Street, Allentown, Pa.

1905. WALKER, WILLIAM H. Professor of Industrial Chemistry, Massachusetts Institute of Technology, 24 Trinity Place, Boston, Mass.

1904. *WALLACE, E. C. Chemist, Warren Brothers Company, Post Office Box 42, Cambridgeport, Mass.

1903. *WALSH, W. F. American Brake Shoe and Foundry Company, 408 Allen Avenue, Richmond, Va.

1903. *WALTER, LEE W. Cement Inspector, Erie Railroad, Ninth and Provost Streets, Jersey City, N. J.

1905. *WARD, C. E. Oil Inspector, Pittsburg Coal Company, Banksville, Pa.

1904. WARDELL, H. R. General Sales Agent, Barber Asphalt Paving Company, Ardmore, Pa.

1905. *WARMAN, F. C. United States Assistant Engineer, 1000 Twenty-second Street, Washington, D. C.

1903. WARNER, GEORGE C. Sullivan Machinery Company, P. O. Box 33, Claremont, N. H.

1905. WARREN BROTHERS COMPANY, 93 Federal Street, Boston, Mass.

1904. WASON, LEONARD C. President, Aberthaw Construction Company, 8 Beacon Street, Boston, Mass.

1904. WEBB, Z. Chief Chemist, Eliza Furnace, Jones and Laughlin Steel Company, *For Mail:* 861 Lilac Street, Pittsburg, Pa.

1900. WEBSTER, GEORGE S. Chief Engineer and Surveyor, Bureau of Surveys, 318 City Hall, Philadelphia, Pa.

1898. *WEBSTER, WILLIAM R. Civil Engineer, 411 Walnut Street, Philadelphia, Pa.

1904. WELLS, J. WALTER. 932 Markham Street, Toronto, Canada.

1903. *WEMLINGER, J. R. Assistant Sales Agent, Cambria Steel Company, 71 Broadway, New York, N. Y.

1904. WENTWORTH, CHARLES C. Principal Assistant Engineer, Norfolk and Western Railway, Roanoke, Va.

1905. WENTZ, DANIEL B. President, Stonega Coal and Coke Company, 1723 Land Title Building, Philadelphia, Pa.

1897. WEST, THOMAS D. Foundry Expert, Sharpsville, Pa.

1904. WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY. L. A. Osborne, Vice-President, P. O. Box 911, Pittsburg, Pa.

1905. *WHEELER, FRANK A. Inspecting Engineer, Harrison Building, Philadelphia, Pa.

1905. WHINERY, S. Consulting Engineer on Pavements, etc., Borough of Manhattan, N. Y., 95 Liberty Street, New York, N. Y.

1900. *WHITEHEAD, J. W., JR. Preservative Coatings, 1 Madison Avenue, New York, N. Y.

1902. *WHITNEY, ASA W. Secretary and Metallurgist, Sanford-Day Iron Works, Southern Successors to A. Whitney and Sons' Car Wheel Works, P. O. Box 523, Knoxville, Tenn.

1902. WHITNEY, WILLIS R. Associate Professor of Chemistry, Massachusetts Institute of Technology, Boston, Mass.

1898. WICKHORST, MAX H. Engineer of Tests, Chicago, Burlington and Quincy Railroad, Aurora, Ill.

1904. WIEBUSCH, CHAS. F. Treasurer, West Indies Company, 9 Murray Street, New York, N. Y.

1904. WILCOX, LEWIS G. Inspector of Steel, New York Rapid Transit Railroad Commission, 613 Empire Building, Pittsburg, Pa.

1902. WILHELM COMPANY, THE A. Paint Makers, Reading, Pa.

1903. WILKINS, A. D. Shawnee Farm, Ridgeway, Va.

1898. WILLE, H. V. Assistant to Superintendent, Baldwin Locomotive Works, 500 North Broad Street, Philadelphia, Pa.

1904. WILLIAMS, THOMAS H. President, A. A. Griffing Iron Company, Jersey City, N. J.

1905. WILLIAMSON, SYDNEY B. Consulting Engineer, Equitable Building, Baltimore, Md.

1900. *WING, CHARLES B. Professor of Structural Engineering, Stanford University, Cal.

1904. WISNER, GEORGE Y. Consulting Engineer, United States Reclamation Service, 34 West Congress Street, Detroit, Mich.

1903. WITTMAN, N. B. Potts and Wittman, North American Building, Philadelphia, Pa.

1903. *WOLFEL, PAUL L. Chief Engineer, American Bridge Company, 362 Green Lane, Roxborough, Philadelphia, Pa.

1902. *WOOD AND COMPANY, R. D., Founders. Walter Wood, 400 Chestnut Street, Philadelphia, Pa.

1903. WOOD, ALAN D. Superintendent, Alan Wood Iron and Steel Company, Conshohocken, Pa.

1903. WOOD, EDWARD R., JR. Manufacturer, 400 Chestnut Street, Philadelphia, Pa.

1903. *WOOD, F. W. President, Maryland Steel Company, Sparrows Point, Md.

1900. *WOOD, WALTER. Cast-Iron Pipe Manufacturer, R. D. Wood Company, 400 Chestnut Street, Philadelphia, Pa.

1903. WOODMAN, DURAND. Analytical and Technical Chemist, 80 Beaver Street, New York, N. Y.

1900. *WOOLSON, IRA H. Adjunct Professor of Mechanical Engineering, Columbia University, New York, N. Y.

1904. *WORCESTER, JOSEPH R. Consulting Engineer, 53 State Street, Boston, Mass.

1905. WORCESTER POLYTECHNIC INSTITUTE. William W. Bird, Director of the Department of Mechanical Engineering, Worcester, Mass.

1904. WORMELEY, P. L., JR. Engineer of Tests, Division of Tests, United States Department of Agriculture, Washington, D. C.

1903. WORTHINGTON, CHARLES. Consulting Engineer, 134 West Seventieth Street, New York, N. Y.

1902. WYCKOFF, CHARLES, JR. 185 Penn Street, Brooklyn, N. Y.

1905. WYMAN, H. WINFIELD. Wyman and Gordon, Worcester, Mass.

1904. YAMAMOTO, YOSHIO. Mechanical Engineer, 4153 Girard Avenue, Philadelphia, Pa.

1905. YOUNG, JOHN P. General Manager, Youngstown Car Manufacturing Company, Youngstown, O.

1903. ZEHNDER, C. H. Manager, Rogers, Brown and Warren, Pennsylvania Building, Philadelphia. Pa.

GEOGRAPHICAL DISTRIBUTION OF MEMBERS.

Alabama	4	Maryland	11	South Dakota	2
Arizona	2	Massachusetts	53	Tennessee	2
California	11	Michigan	7	Texas	2
Colorado	8	Minnesota	1	Virginia	25
Connecticut	8	Missouri	14	Washington	3
Delaware	3	Nebraska	3	West Virginia	4
Dist. of Columbia	31	New Hampshire	1	Wisconsin	14
Idaho	1	New Jersey	23	Canada	12
Illinois	52	New York	171	Cuba	1
Indiana	8	North Carolina	1	England	5
Iowa	3	Ohio	34	France	1
Kansas	4	Oregon	1	Germany	2
Kentucky	3	Pennsylvania	219	Philippine Is.	1
Louisiana	1	Rhode Island	3	Russia	1
Maine	3				

Total membership.. 759

Total number holding membership also in the International Association for Testing Materials.. 241

DECEASED MEMBERS.

Name.	Date of Membership.	Date of Death.
J. W. Anderson	1896	May 18, 1905.
W. P. Black	1896	December 12, 1902.
Henry I. Budd	1903	January 14, 1905.
Thomas M. Drown	1899	November 16, 1904
Henry U. Frankel	1903	December 8, 1903.
Charles Jarecki	1896	January 26, 1901.
J. B. Johnson	1899	June 23, 1902.
G. M. McCauley	1898	May 25, 1901.
George S. Morison	1896	July 1, 1903.
Henry Morton	1896	May 9, 1902.
Robert H. Thurston	1896	October 25, 1903.
H. H. Wright	1904	June 22, 1905.

PAST OFFICERS.

NOTE.—The Society, from its organization in 1898 till its incorporation under its present name in 1902, was designated the American Section of the International Association for Testing Materials.

The officers and members of the Executive Committee during this four-year period were as follows:

CHAIRMEN:

MANSFIELD MERRIMAN, 1898–1900.

HENRY M. HOWE, 1900–1902

VICE-CHAIRMEN:

HENRY M. HOWE 1898-1900.

CHARLES B. DUDLEY 1900–1902.

SECRETARIES:

RICHARD L. HUMPHREY, 1898–1900.

J. M. PORTER, 1900–1902

TREASURERS:

PAUL KREUZPOINTNER, 1898–1900.

R. W. LESLEY, 1900–1902

MEMBERS OF EXECUTIVE COMMITTEE:

GUS. C. HENNING, 1898–1900.

ALBERT LADD COLBY, 1900-1902.

TECHNICAL COMMITTEES

OF THE

AMERICAN SOCIETY FOR TESTING MATERIALS.

Committee A, on Standard Specifications for Iron and Steel.

William R. Webster, *Chairman.*
Edgar Marburg, *Secretary.*

American Steel and Wire Company,
F. H. Daniels.
Bethlehem Steel Company,
E. O'C. Acker.
Cambria Steel Company,
George E. Thackray.
Carnegie Steel Company,
W. A. Bostwick.
Central Iron and Steel Company,
James B. Bailey.
Charles S. Churchill.
James Christie.
F. H. Clark.
J. Allen Colby.
Colorado Fuel and Iron Company,
C. S. Robinson.
John Sterling Deans.
P. H. Dudley.
Franklin Institute,
Alex. E. Outerbridge, Jr.
J. E. Greiner.
Robert W. Hunt Company.
Illinois Steel Company,
P. E. Carhart.
Jones and Laughlin Steel Company,
Willis L. King.
Gaetano Lanza.
Lukens Iron and Steel Company,
Charles L. Huston.
S. S. Martin.
Richard Moldenke.
National Tube Company,
Frank N. Speller.
L. R. Pomeroy.
The Osborn Engineering Company,
Frank C. Osborn.
The Pennsylvania Steel Company,
H. H. Campbell.
Reading Iron Company.
Joseph T. Richards.
John A. Roebling's Sons Company,
J. H. Janeway.
C. C. Schneider.
Shelby Steel Tube Company,
J. H. Nicholson.
J. P. Snow.
Standard Steel Works,
A. A. Stevenson.
J. A. L. Waddell.
Samuel T. Wagner.
Max H. Wickhorst.
H. V. Wille.
R. D. Wood and Company,
Walter Wood.

Committee B, on Standard Specifications for Cast Iron and Finished Castings.

Walter Wood, *Chairman.*
Richard Moldenke, *Secretary.*

Hugh W. Adams.
James A. Beckett.
Robert Bentley.
Joseph W. Bramwell.
H. H. Campbell.
Colorado Fuel and Iron Company,
C. S. Robinson.
Albert Ladd Colby.

COMMITTEE B.—*Continued.*

Edgar S. Cook.
H. A. Croxton.
George M. Davidson.
H. E. Diller.
J. K. Dimmick.
W. C. Du Comb.
Charles B. Dudley.
George F. Eldridge.
B. F. Fackenthal, Jr.
L. M. Fenner.
H. E. Field.
A. I. Findley.
Stanley G. Flagg, Jr.
W. K. Hatt.
W. H. Hearne.
J. O. Henshaw.
P. S. Hildreth.
Henry M. Howe.
Illinois Steel Company,
P. E. Carhart.
International Harvester Company,
John C. Hood.
Robert Job.
Jones and Laughlin Steel Company,
Willis L. King.
W. J. Keep.
J. F. Kinkead.
Paul Kreuzpointner.
Gaetano Lanza.
L. R. Lemoine.
William W. Lobdell.
A. E. Loudon.
Charles F. McKenna.
J. W. McQueen.
R. S. MacPherran.
Mansfield Merriman.
Tinius Olsen.
Alex. E. Outerbridge, Jr.
Leonard Peckitt.
L. S. Randolph.
David Reid.
Walter M. Saunders.
Albert Sauveur.
W. G. Scott.
C. W. Sherman.
A. W. Slocum.
Henry Souther.
H. W. Spangler.
Technischer Verein, Pittsburg,
S H. Stupakoff.
Enrique Touceda.
C. H. Vannier.
W. R. Webster.
Thomas D. West.
Asa W. Whitney.
H. V. Wille.
N. B. Wittman.
F. W. Wood.
E. R. Wood, Jr.
I. H. Woolson.
C. H. Zehnder.

COMMITTEE C, ON STANDARD SPECIFICATIONS FOR CEMENT.

GEORGE F. SWAIN, *Chairman.*
GEORGE S. WEBSTER, *Vice-Chairman.*
RICHARD L. HUMPHREY, *Secretary.*

Booth, Garrett & Blair.
Spencer Cosby.
A. W. Dow.
L. Henry Dumary.
W. S. Eames.
A. F. Gerstell.
Edward M. Hagar.
W. H. Harding.
Olaf Hoff.
W. J. Kelley.
Robert W. Lesley.
F. H. Lewis.
John B. Lober.
Andreas Lundteiger.
Charles F. McKenna.
W. W. Maclay.
Charles A. Matcham.
A. W. Munsell.
National Fire Protection Association,
Edward T. Cairns.
Spencer B. Newberry.
James Madison Porter.
Joseph T. Richards.
Clifford Richardson.
L. C. Sabin.
Harry J. Seaman.
Henry S. Spackman Engineering Company.
S. S. Voorhees.

COMMITTEE D, ON STANDARD SPECIFICATIONS FOR PAVING AND BUILDING BRICK.

LOGAN WALLER PAGE, *Chairman.*

Ira O. Baker.
Edward Orton, Jr.
W. D. Richardson.
Arthur N. Talbot.

COMMITTEE E, ON PRESERVATIVE COATINGS FOR IRON AND STEEL.

S. S. VOORHEES, *Chairman.*
JOSEPH F. WALKER, *Secretary.*

W. A. Aiken.
The Joseph Dixon Crucible.
Company
Malcolm MacNaughton.
Charles B. Dudley.
N. F. Harriman.
International Acheson Graphite Company,
C. L. Collins.
Robert Job.
Spencer B. Newberry.
Charles L. Norton.
W. A. Polk.
W. A. Powers.
A. H. Sabin.
G. W. Thompson.
J. W. Whitehead, Jr.
Max H. Wickhorst.
The A. Wilbelm Company,
Charles J. Davies.

COMMITTEE F, ON HEAT TREATMENT OF IRON AND STEEL.

HENRY M. HOWE, *Chairman.*

William Campbell,
Albert Sauveur.
Bradley Stoughton.

COMMITTEE G, ON THE MAGNETIC TESTING OF IRON AND STEEL.

J. WALTER ESTERLINE, *Chairman.*

John A. Capp.
H. E. Diller.
W. A. Layman.
Richard Moldenke.
J. A. Mathews.
C. E. Skinner

COMMITTEE H, ON STANDARD TESTS FOR ROAD MATERIALS.

LOGAN WALLER PAGE, *Chairman.*
ARTHUR N. JOHNSON, *Secretary.*

Ira O. Baker.
W. H. Broadhurst.
A. W. Campbell.
A. Cushman.
A. W. Dow.
A. B. Fletcher.
W. S. Godwin.
W. K. Hatt.
G. B. Hemstreet.
J. A. Holmes.
Jos. W. Hunter
C. A. Kenyon.
Frederic A. Kummer.
Nelson P. Lewis.
A. Marston.
J. J. Morrow.
Clifford Richardson.
George W. Tillson.
Calvin Tomkins.
E. O. Wallace.

COMMITTEE I, ON REINFORCED-CONCRETE.

F. E. TURNEAURE, *Chairman.*
R. W. LESLEY, *Vice-Chairman.*
RICHARD L. HUMPHREY, *Secretary.*

W. B. Fuller.
E. Lee Heidenreich.
A. L. Johnson.
Gaetano Lanza.
Edgar Marburg.
C. M. Mills.
L. S. Moisseff.
H. H. Quimby.
W. P. Taylor.
S. E. Thompson.
S. T. Wagner.
G. S. Webster.

COMMITTEE J, ON STANDARD SPECIFICATIONS FOR FOUNDRY COKE.

C. H. ZEHNDER, *Chairman.*
RICHARD MOLDENKE, *Secretary.*

Warren Blauvelt.
W. H. Blauvelt.
Wm. A. Bole.
Edgar S. Cook.
John Donahoe.
Chas. B. Dudley.
D. T. Evans.
B. F. Fackenthal, Jr.
Geo. H. Finn.
H. L. Haldeman.
J. A. Holmes.
J. A. Kinkead.
John Lloyd.
W. C. Magee.
E. C. Means.
C. L. Prince.
F. Schniewind.
W. G. Scott.
W. B. Snow.
Henry Souther.
D. B. Wentz.
H. V. Wille.
Walter Wood.

COMMITTEE K, ON STANDARD METHODS OF TESTING.

GAETANO LANZA, *Chairman.*

Geo. A. Bostwick.
James Christie.
Chas. B. Dudley.
W. K. Hatt.
Henry M. Howe.
A P. Hume
Richard L. Humphrey.
Mansfield Merriman
Richard Moldenke.
E. D. Nelson.
H. P. Talbot.
Geo. E. Thackray.
H. V. Wille.
Ira H. Woolson.

COMMITTEE L, ON STANDARD SPECIFICATIONS AND TESTS FOR CLAY AND CEMENT SEWER PIPES.

RUDOLPH HERING, *Chairman.*
A. J. PROVOST, JR., *Vice-Chairmau.*
CHARLES F. MCKENNA, *Secretary.*

W. C. Foster.
F. C. Hitchcock.
W. C. Hull.
J. C. Rossi.

COMMITTEE M, ON STANDARD SPECIFICATIONS FOR STAYBOLTS.

H. V. WILLE, *Chairman.*

F. B. Allen.
American Iron and Steel Manufacturing Company.
Brown & Company.
F. H. Clark.
J. A. Kinkead.
E. D. Nelson.
J. C. Ramage.

COMMITEE N, ON STANDARD TESTS FOR LUBRICANTS.

W. M. DAVIS, *Chairman.*
J. M. JEFFERS, *Secretary.*

Bureau of Standards,
S. W. Stratton.
Bureau of Steam Engineering, Navy Department,
W. M. Parks.
W. A. Converse.
A. H. Gill.
E. D. Nelson.
J. H. Pew.
Geo. H. Taber.
C. E. Ward.

COMMITTEE O, ON UNIFORM SPEED IN COMMERCIAL TESTING.

PAUL KREUZPOINTNER, *Chairman.*
H. V. WILLE, *Secretary.*

W. A. Bostwick.
F. O. Bunnell.
H. H. Campbell.
A. P. Hume.
J. A. Kinkead.
Tinius Olsen.
A. A. Stevenson.
C. R. Stewart.

COMMITTEE P, ON FIRE-PROOFING MATERIALS.

IRA H. WOOLSON, *Chairman.*
R. P. MILLER, *Secretary.*

W. W. Ewing.
John R. Freeman,
H. W. Hodge.
Edwin Thacher.
D. E. Waid.
C. W. Somerville

COMMITTEE Q, ON STANDARD SPECIFICATIONS FOR THE GRADING OF STRUCTURAL TIMBER.

HERMANN VON SCHRENK, *Chairman pro tem.*

Chas. H. Davis.
A. O. Elzner.
Geo. H. Emerson.
B. E. Fernow.
W. K. Hatt.
H. W. Lohmann.
R. A. Long.
A. F. Rosenheim.
H. R. Safford.
M. R. Sanguinet.
I. O. Walker.

COMMITTEE R, ON UNIFORM SPECIFICATIONS FOR BOILERS.

E. D. MEIER, *Chairman pro tem.*

F. B. Allen.
R. C. Carpenter.
J. H. Hartley.
Chas. L. Huston.
John McLeod.
Mutual Boiler Insurance Company
R. S. Hale.
J. E. Sague.
H. V. Wille.

COMMITTEE S, ON WATERPROOFING MATERIALS.

W. A. AIKEN, *Chairman.*
A. W. DOW, *Secretary.*

Barrett Manufacturing Company,
Fred L. Kane.
E. W. DeKnight.
T. H. Ellis.
A. W. Munsell.
C. S. Reeve.
W. P. Taylor.
Maximilian Toch.
U. S. War Department,
Capt. Chester A. Harding.
Warren Brothers Company,
A. E. Schutte.

COMMITTEE T, ON THE TEMPERING AND TESTING OF STEEL SPRINGS AND STANDARD SPECIFICATIONS FOR SPRING STEEL.

J. A. KINKEAD, *Chairman pro tem.*

F. O. Bunnell.
Nathan H. Davis.
Alan Lukens.
Archibald M. McCrea.
R. W. Mahon.
E. D. Nelson.
Max. H. Wickhorst.
H. V. Wille.

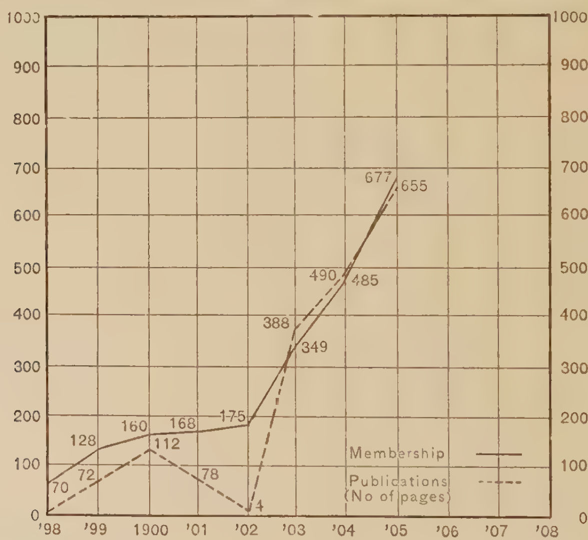
COMMITTEE U, ON STANDARD SPECIFICATIONS AND TESTS FOR WIRE ROPE.

(In course of organization.)

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Since the Seventh Annual Meeting of the Society, the Executive Committee has held five regular quarterly meetings and one special meeting. Three of these meetings were informal, owing to the absence of a quorum. An abstract of the minutes of these meetings is appended to this report.

The progress of the Society during the past year exceeds all previous records. The membership has grown from 485 to 677.



The increased volume of the Proceedings has kept almost exact pace with the increased membership, having risen from 490 to 655 pages. The proceeds from the sale of publications has increased from $182.84 to $430.84. The statistics of the Society as to membership and publications from its organization in 1898 till 1905, inclusive, are shown in the accompanying diagram. The number of standing technical committees has been increased from 11 to 18 during the year. Thirteen of these committees will present reports at this meeting. The financial status of the Society shows marked improvement. Owing to the large increase of

membership and the increase of $2.00 in annual dues it has not been found necessary during the past year to issue a general appeal for subscriptions. Nevertheless, the Society is still dependent in no small measure on its contributing members and special subscribers for its financial maintenance as may be seen from the subjoined report of the Treasurer. It is confidently expected, however, on the basis of recent progress, that the Society will soon become wholly self-sustaining.

The statistics for the year are set forth in more detail below:

Membership.—The membership at the last annual meeting was 485. Since then 220 new applications for membership have been received and approved. The Society has suffered a loss of three members through death: Thomas M. Drown died on November 16, 1904; Henry I. Budd, on January 14, 1905, and J. W. Anderson, on May 18, 1905. The number of resignations for the year is 15, and 10 members were dropped for arrears in dues. It is significant of the firm position to which the Society has attained that, notwithstanding the increase of dues and the largely increased membership the number of resignations for the year is only one greater than for the year immediately preceding. The total loss from all causes is 28, leaving a net gain of 192, as against 136 for the year before, and making the total membership at present 677. It is worthy of note that the net gain for the year is substantially larger than the total membership three years ago, or four years after the organization of the American branch of the International Association.

Publications.—In addition to the annual volume of the Proceedings (Vol. IV, 655 pp.), a pamphlet of 86 pages, containing the list of members and other data concerning the Society, was issued, as well as seven official circulars of information.

New Committees.—Partly in pursuance of action at the last annual meeting and partly at the initiative of the Executive Committee, the list of technical committees has been increased as follows:

Committee J.—On Standard Specifications for Foundry Coke.

Committee K.—On Standard Methods of Testing.

Committee L.—On Standard Specifications and Tests for Sewer Pipes.

Committee M.—On Standard Specifications for Staybolts.

Committee N.—On Standard Tests for Lubricants.

Committee O.—On Uniform Speed in Commercial Testing.

Committee P.—On Fire-Proofing Materials.

Committee Q.—On Standard Specifications for the Grading of Structural Timber.

The designation of Committee K on Standard Tests for Boilers has been changed to Committee R on Boilers. The number of technical committees is now 18. The personnel of these committees appears in *Appendix II* to this report.

Finances.—The financial condition of the Society is sound, as may be seen from the following report for the year on the part of the Treasurer. The cash balance is $604.85, and there are no unpaid bills on hand. It is to be observed, however, that no remittances have been made to the International Association on account of dues for the current fiscal year, for reasons to be noted hereafter.

ANNUAL REPORT OF THE TREASURER.

From June 10, 1904, to June 10, 1905.

RECEIPTS.		
Membership dues	$2,923 00	
Contributing membership dues	850 00	
Subscriptions	985 00	
Sale of publications	430 84	
Reprints	160 59	
Orders for binding	141 30	
International Association	32 16	
Excess remittances	9 37	
Interest on deposits	24 22	
Total receipts	$5,556 48	
Cash balance, June 10, 1904	469 68	
		$6,026 16
DISBURSEMENTS.		
Membership dues, International Association	$324 00	
Printing, engraving, binding, stationery, etc.	2,701 48	
Secretary's salary	1,500 00	
Clerical services	398 00	
Expenses Secretary's office	248 10	
Stenographer, Seventh Annual Meeting	166 63	
Account of International Association	32 16	
Committee expenses	42 04	
Excess remittances, refunded	8 90	
Total disbursements	$5,421 31	
Cash balance, June 10, 1905	604 85	
		$6,026 16

The lists of Contributing Members and Subscribers follow:

CONTRIBUTING MEMBERS.

Ajax Metal Company,
Cambria Steel Company,
Carnegie Steel Company,
Central Iron and Steel Company
Dixon, R. M.,
Dudley, Charles B.,
Goodnow, C. A., representing the Chicago and Alton Railroad,
Harahan, J. T., representing the Illinois Central Railroad,
Illinois Steel Company,
Jones and Laughlins, Limited,
Latrobe Steel Company,
Lesley, R. W.,
Lukens Iron and Steel Company,
McLeod, John,
Mitchell, Joseph,
Orford Copper Company,
Pennsylvania Steel Company,
Polk, W. A.,

Total 18

SUBSCRIBERS.

Chicago, Milwaukee and St. Paul Railway Company	$25 00
Fackenthal, Jr., B. F.	10 00
U. S. Steel Corporation	950 00
	$985 00

Relations with the International Association for Testing Materials.—The International Association sustained a great loss during the year in the death of its President, Professor L. von Tetmajer, which occurred on January 31, 1905. At the first meeting of the Executive Committee following this sad occurrence, the following memorial minute was adopted:

"The Executive Committee has learned with profound regret of the death of Professor L. von Tetmajer, the honored President of the International Association for Testing Materials His death removes a commanding figure from the field of applied science, especially in the branches pertaining to the testing of materials, in which he had achieved a world-wide reputation. For many years, and up to the time of his death, he labored unselfishly and unremittingly in the advancement of the interests of the International Association. The Executive Committee desires to record its recognition of the great value of his services and its deep sense of loss at his untimely removal from our midst."

Mr. Franz Berger, Chief Engineer of the Department of Public Works, Vienna, Austria, has been appointed Acting President.

The relations of the Society with the International Association have been confined during the past year, as usual, to routine correspondence. Three months ago the unexpected and unwelcome news was received that the International Council had decided for the third time to postpone the next Congress for another year. In pursuance of the action taken at the Third Congress, convened in Buda-Pesth, in 1901, the Fourth Congress should have been held in 1903. The first postponement till 1904 was based on the ground that this would give the Committees a better opportunity to complete their labors. The second postponement of the Congress which was to have been held in St. Petersburg, Russia, in 1904, was attributed to the war in the Far East. It was later decided to hold this Congress in Brussels in 1905, but owing to circumstances concerning which your Executive Committee has received no definite information, it has been determined to postpone this Congress for a third time, and it is now announced that it will be held in Brussels in 1906.

During the four years that have intervened since the last Congress the members of the Association have received practically nothing beyond the minutes of the Third Congress; and the minutes of the annual meetings of the Council, and these only after long delays. Not even a list of members has been issued during that period, a period during which our own remittances have aggregated nearly two thousand dollars. Nor is it clear, at least from the American standpoint, why the causes that operated to induce the abandonment, first, of the proposed St. Petersburg Congress; second, of the proposed Brussels Congress, should have precluded the holding of a congress in some other city and country during either of these years.

According to recent announcements the Council proposes to commence this year the publication of the reports of certain Committees and Referees in English, German and French, and to distribute these among the members free of charge, in whatever language may be preferred. A list of members, correct until June 1, 1905, is also promised.

It is becoming more and more evident that the feeling of many of our members towards the International Association is one of growing indifference or dissatisfaction. It is believed, also, that the great majority of new members have joined the American

Society wholly irrespective of any expected advantage incident to their membership in the International Association. In the judgment of the Executive Committee, the time has come to consider whether in fairness to the interests of the American Society, membership in the International Association, with attendant dues, shall continue to be a *sine qua non* to membership in the Society. It is believed that this should properly be left to the free choice of the individual members, and it is accordingly proposed to amend the By-Laws as previously announced in Circular No. 20, viz.:

Present By-Laws.

ARTICLE I.

SECTION 1. Any person, corporation or technical society holding membership in the International Association for Testing Materials is eligible for membership.

SEC. 2. Any person, corporation or society can become a member of this Society and of the International Association for Testing Materials simultaneously upon being proposed by two members of this Society and being approved by its Executive Committee.

SEC. 3. Any member who subscribes annually the sum of fifty dollars ($50) toward the general funds of the Society shall be designated a Contributing Member, his rights and privileges as a member remaining unchanged.

ARTICLE IV.

SECTION 2. The annual dues of each member shall be $5.00. Of this amount $1.50 shall be transmitted by the Secretary to the International Association for Testing Materials. The remainder shall be applied to the treasury of the Society.

Proposed Amended Form.

ARTICLE I.

SECTION 1. Any person, corporation or technical society can become a member of this Society upon being proposed by two members and being approved by the Executive Committee.

SEC. 2. Any member who subscribes annually the sum of fifty dollars ($50) towards the general funds of the Society shall be designated a contributing member, his rights and privileges as a member remaining unchanged. Contributing members shall be exempt from the regular membership dues.

ARTICLE IV.

SECTION 2. The annual dues of each member shall be $5.00. Members holding membership also in the International Association for Testing Materials shall pay annually the additional sum of $1.50, which shall be transmitted by the Secretary to the International Association.

The practical effect of these amendments would be to increase the yearly revenues of the Society from dues about a thousand dollars on the basis of the present membership, and to increase, by $1.50 per annum, the dues of those members only who may wish to continue their connection with the International Association. This would greatly hasten the day when the Society will find itself on a strictly self-sustaining footing, that is to say, entirely independent of subscriptions or contributions in any form. It is believed to be the unanimous sentiment of the membership that such a condition should be realized as speedily as possible.

If the third postponement of the Congress could have been anticipated, some such action as is now proposed would doubtless have been recommended a year ago, and was, in fact, under consideration by the Executive Committee at that time. The matter was held in abeyance merely to await the outcome of the Congress announced for this year. The first notice of the third postponement was received three months after the beginning of the present fiscal year. Under these circumstances the Executive Committee decided to withhold all remittances to the International Association on account of dues for the current year, pending an expression of the sense of the membership at large at the annual meeting, and eventually by letter-ballot, on the above proposed amendments of the By-Laws, and in case these should be favored, on the question of limiting the remittances for the current fiscal year, beginning on January 1, 1905, to the dues of such members only as may decide to maintain their connection with the International Association. The dues of the remaining members would, in that case, be refunded according to individual option.

The conclusions of the Executive Committee on this important subject are offered as the result of the most careful deliberation, and in the full realization of their possibly far-reaching effect on the future, both of the International Association and the American Society. It is believed, however, that the time has come to face the issue squarely.

Engineering Standards Committee of Great Britain.—At the last annual meeting attention was called to the fact that in England the Engineering Standards Committee, organized under the auspices of the five leading technical societies of Great Britain and enjoying the liberal financial support of the govern

ment, is operating on lines similar to those followed by our own committees. The visit to America last fall of the Secretary of the English Committee, "to study the question of Standardization in the United States and Canada," afforded an opportunity to establish closer relations with that Committee. A meeting of our Committee A on Standard Specifications for Iron and Steel was held in New York at the house of the American Society of Civil Engineers especially with a view of meeting the Secretary and comparing notes. The following excerpts are quoted from the printed report of the Secretary to his Committee:

"The Association which has done more than any other to introduce practical standards into America for engineering practice is the American Society for Testing Materials....... The American Society for Testing Materials forms what might be called a clearing-house for standard specifications in America, as the specifications issued by other societies cited in this report are brought up for discussion at their meetings, amended where necessary, and adopted. In regard to the representation of manufacturers and other similar matters, the American Society for Testing Materials appears to be organized very much on the same lines as the Engineering Standards Committee.......

The committees of the American Society for Testing Materials being composed in nearly equal proportion of engineers and manufacturers, any specification adopted by the Society is, owing to the representation of the manufacturers or the committees, generally worked to by manufacturers throughout the country.

"In regard to the unification of specifications between the two countries, there is no doubt that a closer cooperation between our Committee and the American Society for Testing Materials would lead to a harmonizing of methods of testing, and where the practice permitted it, of specifications. The essential differences in practice existing in the two countries will prevent any complete harmonization of sections and specifications; but there are many points upon which cooperation might be secured to the mutual advantage of both countries. This could be assisted by more complete interchange of views between the Engineering Standards Committee and the Amercian Society."

It is believed that the members of this Society are in full sympathy with the views expressed in the concluding paragraph and will gladly cooperate to that end.

Committee A on Standard Specifications for Iron and Steel held a largely attended and very successful meeting in Philadelphia last fall. The meeting extended over two days and embraced four sessions. It would seem desirable to adopt as an annual feature

in the activities of the Society a general fall meeting of its standing technical committees. The various committees might hold separate sessions to be followed by joint sessions in groups between committees whose work is more or less closely related. Such an arrangement would tend to stimulate interest in committee work, and would prove especially convenient to those holding membership in more than one committee.

Respectfully submitted on behalf of the Executive Committee,

EDGAR MARBURG, *Secretary.*
CHARLES B. DUDLEY, *President.*

REPORT OF AUDITING COMMITTEE.

PHILADELPHIA, June 24, 1905.

To the Executive Committee of the American Society for Testing Materials:

We have examined the books and accounts of the Secretary-Treasurer from January 7, 1905, the date of the last audit, to June 10, 1905, the date of the annual report of the Treasurer, and find the cash balance of $604.85 to be correct.

[Signed]
R. W. LESLEY,
J. A. COLBY,
Auditing Committee.

APPENDIX.

ABSTRACT OF MINUTES OF THE EXECUTIVE COMMITTEE.

Regular Meeting, June 18, 1904.—Hotel Traymore, Atlantic City, N. J. Present: Messrs. Dudley and Marburg.

In the absence of a quorum the meeting was declared informal with the understanding that any action taken would be subject to the approval of the Executive Committee at its next meeting.

The Secretary reported the receipt of 51 applications for membership, duly approved; 2 resignations and the dropping of 3 members for arrears in dues, making the total membership 485.

It was decided that if the amendment relative to increasing the dues from $3.00 to $5.00 per annum be carried by letter-ballot of the Society, its enforcement shall date from January 1, 1905, the beginning of the next fiscal year.

The Secretary was authorized to engage a clerk for three months, at a salary of $50 per month.

Regular Meeting, October 22, 1904.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Christie, McLeod and Marburg, of the Executive Committee, and Mr. W. R. Webster on invitation.

The action taken at the last quarterly meeting on June 18, in the absence of a quorum, was duly approved.

The Secretary reported the receipt of 90 applications for membership, duly approved, making the total membership 575.

The revised Specifications for Foundry Pig Iron, Locomotive Cylinders and Malleable Castings were referred to letter-ballot in pursuance of instructions at the Annual Meeting.

It was decided to appoint Committees on:

Standard Specifications for Foundry Coke.
Standard Specifications and Tests for Sewer Pipe.
Standard Tests for Lubricants.
Uniform Speed in Commercial Testing.
Fireproofing Materials.

It was decided to abolish Committee J on Corrosion of Metals, and to refer this subject to Committee E.

The financial relations of the Society with the International Association were considered, and it was decided to take no action in the matter before the next Congress, scheduled for August, 1905.

Special Meeting, December 10, 1904.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Lesley, McLeod and Marburg.

The Secretary reported that the recent letter-ballot had been canvassed by a committee appointed by the President, consisting of Messrs. H. H. Quimby and W. P. Taylor, with the following results:

Total number of ballots received	139
Ballots rejected as irregular	2
Total number of legal ballots	137

	For	Against
On amendment of By-Laws increasing annual dues from $3.00 to $5.00	115	19
On the adoption of the proposed standard specifications		
For Cement	110	4
For Foundry Pig Iron	98	4
For Pipe and Special Castings	99	2
For Locomotive Cylinders	94	4
For Malleable Castings	85	3

It was decided to appoint committees on:

Standard Specifications for the Grading of Structural Timber.

Standard Methods of Testing.

In view of the increased membership dues, the Secretary was authorized to announce a corresponding increase in the price of the publications of the Society, with the understanding that the members of the Society would be given an opportunity till February 1, 1905, to complete their files at the former prices

REGULAR MEETING, January 7, 1905.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Christie and Marburg.

In the absence of a quorum the meeting was declared informal, with the understanding that any action taken would be subject to the approval of the Executive Committee at its next meeting.

The Secretary reported the receipt of 41 new applications for membership, duly approved, 10 resignations and the loss of one member by death—Thos. M. Drown, who died on November 16, 1904, making the total membership 605.

A report was submitted on behalf of the Auditing Committee, consisting of Messrs. R. W. Lesley and J. A. Colby, to the effect that the cash balance of $740.27 on December 31, 1904, was found correct.

The Secretary was authorized to reprint Bulletins 1 to 4, inclusive together with title page and Table of Contents for Volume I.

The Secretary was instructed to advise President Tetmajer that it is the sense of the Executive Committee that full recognition should be given to the English language in connection with the printing of the official proceedings and papers of the next International Congress

REGULAR MEETING, April 10, 1905.—Engineers' Club of Philadelphia, 1122 Girard Street, Philadelphia, Pa. Present: Messrs. Dudley, Lesley, Christie McLeod and Marburg.

The action taken at the last quarterly meeting on January 7, in the absence of a quorum, was duly approved.

The Secretary reported the receipt of 63 applications for membership, duly approved, 5 resignations, and the loss of one member by death—Henry I. Budd, who died on January 17, 1905, making the total membership 662.

The following memorial minute was adopted on the death of Prof. L. von Tetmajer, President of the International Association for Testing Material, which occurred on January 31, 1905.

"The Executive Committee has learned with profound regret of the death of Professor L. von Tetmajer, the honored President of the International Association for Testing Materials. His death removes a commanding figure from the field of applied science, especially in the branches pertaining to the testing of materials, in which he had achieved a world-wide reputation. For many years, and up to the time of his death, he labored unselfishly and unremittingly in the advancement of the interests of the International Association. The Executive Committee desires to record its recognition of the great value of his services and its deep sense of loss at his untimely removal from our midst."

A proposal from the Society for the Promotion of Engineering Education, that their annual meeting be held in affiliation with our own, was approved, provided mutually satisfactory arrangements could be made, and with the understanding that not more than one session be held jointly by the two organizations

The Secretary announced that he had just received notice from the Secretary of the International Association to the effect that the Council had decided to again postpone the International Congress for another year. After full discussion, it was decided to propose to the International Council that hereafter membership in the American Society should not necessarily entail membership in the International Association, but should be left to the individual option of the members.

The effect of such a change on the By-Laws was considered, and the Secretary was instructed to take the necessary steps towards the suitable amendment of the By-Laws at the next Annual Meeting, with the understanding that the annual dues in the American Society for Testing Materials are to be fixed at $5.00, and that those members who wish to hold membership also in the International Association are to be subjected to additional dues of $1.50 per annum.

The Treasurer was instructed to remit to the management of the International Association the balance due on membership dues for 1904, but to make no additional remittances pending further instructions.

The Secretary was authorized to deposit the exchanges of the Society in the library of the University of Pennsylvania, in recognition of the courtesy of the library administration in providing for the proper storage

of the stock of Proceedings, and with the understanding that the full privileges of that library shall be accorded to the members of the Society.

The President and Secretary were authorized to open negotiations with Robert Atkinson, of London, Eng., the publisher of the specifications, standards, etc., formulated by the British Engineering Standards Committee, for the publication and handling of the Standard Specifications of the Society on a similar basis; the understanding being that this would involve no expense to the Society, but that it might possibly be made a source of revenue, and that all published matter would be strictly within the control of the Society.

REGULAR MEETING, June 24, 1905.—Engineers' Club of Philadelphia, Philadelphia, Pa. Present: Messrs. Lesley, Christie and Marburg.

In the absence of a quorum, the meeting was declared informal, with the understanding that any action taken would be subject to the approval of the Executive Committee at its next meeting.

The Secretary reported the receipt of 26 applications for membership, duly approved, and the dropping of 10 members for arrears in dues, making the total membership 677.

The Treasurer announced a subscription of $1000 from the United States Steel Corporation of which $50 was to be applied to the annual dues of the Carnegie Steel Company, as a contributing member.

A vote of thanks was passed in acknowledgment of this subscription.

The proposed Annual Report of the Executive Committee was approved.

A report was submitted on behalf of the Auditing Committee, consisting of Messrs. R. W. Lesley and J. A. Colby, to the effect that the cash balance of $604.85 on June 10, 1905, was found correct.

The Secretary called attention to certain unauthorized reprints from the copyrighted proceedings, and it was decided to call the attention of the members to the rule that no reprints are permissible except by authority of the Executive Committee, and that proof of proposed reprints, including title page, must be submitted to the Secretary for approval.

The Secretary was authorized to engage a clerk for three months at a salary of $50 per month.

LIST OF PUBLICATIONS.

TABLE OF CONTENTS

NOTE.—The Society, from its organization in 1898 till its incorporation under its present name in 1902, was designated the American Section of the International Association for Testing Materials. During this period twenty-eight (28) Bulletins were issued, which, collectively, constitute Volume I. of the Proceedings. In 1902 it was decided to publish the Proceedings in the form of annual volumes. Volume II. is the first volume of this new series.

VOLUME I.

VOLUME II.

APPENDICES.

VOLUME III.

Specifications for Iron and Steel Structures Adopted by the American Railway Engineering and Maintenance of Way Association, in March, 1903, with Introduction by J. P. Snow, Chairman.

Specifications for Locomotive Axles and Forgings, Recommended by a Committee of the American Railway Master Mechanics' Association, in June, 1903, with Introduction by F. H. Clark, Chairman.

Specifications for Steel Rails Adopted by the American Railway Engineering and Maintenance of Way Association, in March, 1902, and the Modifications Submitted in March, 1903; William R. Webster, Chairman.

Specifications for Boiler Plate, Rivet Steel, Steel Castings, and Steel Forgings, Recommended by a Committee of the American Society of Mechanical Engineers; H. W. Spangler, Chairman.

Manufacturers' Standard Specifications as Revised in February, 1903, and Their Comparison with Other Recent Prominent Specifications. Albert Ladd Colby.

The Requirements for Structural Steel for Ship-building Purposes. Topical Discussion, opened by E. Platt Stratton.

Springs and Spring Steels. William Metcalf.

The Rolling of Piped Rails. Topical Discussion, opened by Albert Sauveur and Robert Job.

The Casting of Pipeless Ingots by the Sauveur Overflow Method. Albert Sauveur and Jasper Whiting.

Nickel Steel: Its Properties and Applications. Albert Ladd Colby.

Alternate Stresses in Bridge Members. Gustav Lindenthal.

The Constitution of Cast Iron. William Campbell.

Machine-cast Sandless Pig Iron in Relation to the Standardizing of Pig Iron for Foundry Purposes. Edgar S. Cook.

The Physical Properties of Malleable Castings as Influenced by the Process of Manufacture. Richard G. Moldenke.

Cast Iron: A Consideration of the Reactions Which Make it Valuable. Herbert E. Field.

The Importance of Adopting Standard Sizes of Test Bars for Determining the Strength of Cast Iron. Alexander E. Outerbridge, Jr.

The Demand for a Specified Grade of Cast Iron. W. G. Scott.

Cast Iron for Dynamo and Motor Frames. H. E. Diller.

The Light Aluminum Alloys. J. W. Richards.

The Testing of Bearing Metals. G. W. Clamer.

The Master Car Builders' Drop-testing Machine as Installed at Purdue University. W. F. M. Goss.

Stremmatograph Tests of Unit Fiber Strains and Their Distribution in the Base of Rails under Moving Locomotives. Cars, and Trains. P. H. Dudley.

The Control of the Finishing Temperature of Steel Rails by the Thermomagnetic Selector. Albert Sauveur and Jasper Whiting.

A Direct-reading Apparatus for Determining the Energy Losses in Transformer Iron. J. Walter Esterline.

The United States Road Material Laboratory Its Aims and Methods. L. W. Page and A. Cushman.

A Preliminary Program for the Timber Test Work to be Undertaken by the Bureau of Forestry, United States Department of Agriculture. W. K. Hatt.

A Brief Account of the History and Methods of the International Railway Congress. P. H. Dudley.

The Testing of Bitumens for Paving Purposes. A. W. Dow.

Soundness Tests of Portland Cement. W. P. Taylor.

Portland Cement Mortar Exposed to Cold. C. S. Gowen.

Some Observations on the Effect of Water and Combinations of Sand upon the Setting Properties and Tensile Strength of Portland and Natural Cements. E. S. Larned.

Tests on the Compressive Strength of Concrete and Mortar Cubes. C. H. Umstead.

VOLUME IV.

Summary of Proceedings of the Seventh Annual Meeting.

The Influence of Specifications on Commercial Products—Annual Address by the President, Charles B. Dudley.

Report of Committee A on Standard Specifications for Iron and Steel. Discussion.

Report of Committee B on Standard Specifications for Cast Iron and Finished Castings.

1. Proposed Standard Specifications for Foundry Pig Iron.
   Chemical Specifications for Pig Iron. B. F. Fackenthal.
   Specifications for Cast Iron and Finished Castings. Richard Moldenke.
2. Proposed Standard Specifications for Cast Iron Pipe and Special Castings.
3. Proposed Standard Specifications for Locomotive Cylinders.
4. Proposed Standard Specifications for Cast Iron Car Wheels.
5. Proposed Standard Specifications for Malleable Castings.
6. Proposed Standard Specifications for Gray Iron Castings.

Standard Specifications for Foundry Pig Iron, as adopted November 14, 1904.

Report of Committee C on Standard Specifications for Cement.

Report of Committee E on Preservative Coatings for Iron and Steel.

Report of Committee G on the Magnetic Testing of Iron and Steel.

Report of Committee H on Standard Tests for Road Materials.

Specifications for Steel Rails, American Railway Engineering and Maintenance of Way Association, as Amended and Adopted in March, 1904; Wm. R. Webster, Chairman.

Specifications for Iron and Steel Structures, American Railway Engineering and Maintenance of Way Association, as Amended and Adopted in March, 1904; J. P. Snow, Chairman.

Comparison of the Specifications for Axles and Forgings, Proposed by Committees of the American Railway Master Mechanics' Association and the American Society of Mechanical Engineers, with the Standard Specifications Adopted by the American Society for Testing Materials. H. V. Wille.

Alloy Steels. William Metcalf.

A Brief Review of the Status of Testing in the United States. Gaetano Lanza.

The Early Use of 60,000-pound Steel in the United States. Samuel Tobias Wagner.

The Classification of Iron and Steel. Albert Sauveur.

A Proposed Test for Detecting Brittleness in Structural Steel. J. P. Snow.
Appendix. Experimental Studies of the Causes of Brittleness of Steel. Ch. Fremont.

Tests for Detecting Brittle Steel. Wm. R. Webster.

Tensile Impact Tests of Steel. W. K. Hatt.

Staybolt Iron and Machine for Making Vibratory Tests. H. V. Wille.

Bending Moments in Rails. P. H. Dudley.

The Desirability of a Uniform Speed for Commercial Testing. Paul Kreuzpointner.

Cast Iron: Strength, Composition, Specifications. W. J. Keep.

Pig Iron Feasts and Famines: Their Causes and How to Regulate Them George H. Hull.

Structure of Alloys. William Campbell.

A New Chuck for Holding Short Test Pieces. T. D. Lynch.

The Commercial Testing of Sheet Steel for Electrical Purposes. C. E. Skinner.

Permeability of Cast Steel. H. E. Diller.

Specifications for Air-Brake Hose. Max H. Wickhorst.

The Effects of Preservative Treatments on the Strength of Timber. F. A. Kummer.

Results of an Investigation Concerning Causes of Durability of Paints for Structural Work. Robert Job.

Preservative Coatings for Iron and Steel. Cyril de Wyrall.

Some Statistics of the Cement Industry in America. R. W. Lesley.

Practical Cement Control. Charles W. McKenna.

Some Possible By-Products in the Portland Cement Industry. Clifford Richardson.

Some Notes on the Boiling Test for Cement. Frederick H. Lewis.

Tests of Reinforced Concrete Beams: A. N. Talbot, F. E. Turneaure, Edgar Marburg.

Discussion of the three preceding papers.

The Mechanical Defects of Sieves Used in Determining the Fineness of Cement. E. W. Lazell.

Some Attempts to Limit the Personal Equation in Cement Testing. W. A. Aiken.

PRICE LIST.

Volume I., containing Bulletins Nos. 1 to 28, inclusive (266 pp.)	$3 00
Separate Bulletins	15
Volume II., (388 pp.)	5 00
Volume III., (490 pp.)	5 00
Volume IV., (655 pp.)	5 00
Volume V., (565 pp.)	5 00

Libraries, publishers and book-dealers are allowed a discount of 20 per cent. on the above prices.

Members of the Society may obtain back publications for the completion of their personal files at the following special prices:

Volume I	$2 00
Volumes II., III., IV. and V.—Price per volume	3 00

STANDARD SPECIFICATIONS

ADOPTED BY THE

American Society for Testing Materials.

Note:—The formulation and adoption of Standard Specifications for the various materials of engineering is one of the important functions of the Society. These specifications are revised from time to time to meet changed conditions.

The following complete list of Standard Specifications, in their latest revised form, is here given for convenience of reference:

1. Standard Specifications for Structural Steel for Bridges, Vol. V, pp. 48–52.
2. Standard Specifications for Structural Steel for Ships, Vol. I, pp. 81–86, Bulletin, No. 8.
3. Standard Specifications for Structural Steel for Buildings, Vol. I, pp. 87–92, Bulletin, No. 9.
4. Standard Specifications for Open Hearth Boiler Plate and Rivet Steel, Vol. I, pp. 93–100, Bulletin, No. 10.
5. Standard Specifications for Steel Rails, Vol. I, pp. 101–106, Bulletin, No. 11.
6. Standard Specifications for Steel Splice Bars, Vol. I, pp. 107–110, Bulletin, No. 12.
7. Standard Specifications for Steel Axles, Vol. V, pp. 56–58.
8. Standard Specifications for Steel Tires, Vol. I, pp. 115–118, Bulletin, No. 14.
9. Standard Specifications for Steel Forgings, Vol. V, pp. 59–62.
10. Standard Specifications for Steel Castings, Vol. V, pp. 53–55.
11. Standard Specifications for Wrought Iron, Vol. I, pp. 231–236, Bulletin, No. 24.

12. Standard Specifications for Foundry Pig Iron, Vol. IV, pp. 103–104.
13. Standard Specifications for Cast Iron Pipe and Special Castings, Vol. IV, pp. 57–66.
14. Standard Specifications for Locomotive Cylinders, Vol. IV, pp. 69–70.
15. Standard Specifications for Cast Iron Car Wheels, Vol. V, pp. 65–70.
16. Standard Specifications for Malleable Castings, Vol. IV, pp. 95–96.
17. Standard Specifications for Gray Iron Castings, Vol V, pp. 71–74.
18. Standard Specifications for Cement, Vol. IV, pp. 107–110.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

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FRANZ BERGER.

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SECRETARY.

ERNEST REITLER,
Vienna, Austria.

Communications for the International Association should be directed to the International Association for Testing Materials, Technische Hochschule, Karlsplatz, Vienna, IV, Austria.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

BY-LAWS.

Adopted at the Buda-Pesth Congress, 1901.

SECTION 1. The Association shall be called "THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS."

SEC. 2. The objects of the Association are: the development and unification of standard methods of testing; the investigation of the technically important properties of the materials of construction and other materials of technical importance, and also the perfecting of apparatus used for this purpose.

These objects will be furthered:

1. By the Congresses and other meetings of the Association.
2. By the publication of an official Journal.
3. By any other means that may appear desirable.

SEC. 3. The funds necessary for carrying out the purposes mentioned in Section 2 will be raised by

1. The annual subscriptions of members.
2. Profits from the official Journal.
3. Other contributions.

SEC. 4. Any person may become a member upon being proposed by two members of the Association.

Official bodies and technical societies can be elected directly on their sending in their application for membership.

Applications for membership must be sent in writing to the President or to a member of the Council.

Resignations of membership must be sent in the same way.

SEC. 5. It is the duty of every member to further the interests of the Society to the best of his ability.

Every member is required to pay an annual subscription of at least 6 Mks. = 6 shillings = $1.50.*

The Council is authorized to increase the annual subscription in order to cover extraordinary expenses incurred in the interests of the Association.

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* Subscriptions are to be paid to the duly appointed collectors in each country, the card of membership serving as a receipt. Subscriptions not paid by the first of July are collected through the post-office.

SEC. 6. Every member has the right to obtain the Journal of the Association, during the period for which his subscription has been paid, on paying the fixed reduced price.*

SEC. 7. The Association will hold a Congress, as a rule, every second year.

The arrangements for the Congresses will be discussed at general meetings and in meetings of the different sections.

Sections will be formed for the different groups of materials as may be considered necessary.

At present there are three sections:

I. Metals.

II. Natural and artificial building stones, cements and mortars.

III. Other materials of technical value.

Any special questions relating to the subjects of the different sections will be considered at sectional meetings.

The members assisting at the sectional debates, under the presidency of a member of the Council, will appoint the governing bodies of the different sections.

The results of the deliberations of the different sections must be communicated at a general meeting which will pass resolutions embodying the proposals of the sections.

Reports of Commissions, proposals of the Council and other matters to be laid before the Congress, will be printed in German, French and English, and will be sent (in the language preferred) to all members who have announced their intention of taking part in the Congress, within fourteen days before the meeting of the Congress, if possible.

The decisions of the Congress will be printed in all three languages and sent to all members of the Association.

SEC. 8. The Council of the Association will transact all necessary business connected with the Association.

The Council will consist of the President and the duly elected members.

Every country represented in the Association by at least twenty members has the right to propose one member as member of the Council.

The President will be elected by the Congress, the Council by the members belonging to the different countries.

* The reduced price has been fixed at 10 Mks. = 10 shillings = $2.50. This sum may be sent in with the subscriptions. The yearly volumes begin on January 1.

Till such election has taken place the former members of the Council remain in office.

The names of proposed new members of the Council have to be communicated to the President before each Congress.

The two Vice-Presidents will be elected by the Council from among its own members.

The Council is entitled to transact business when it has been duly called together according to rule and when the President or one of the Vice-Presidents is present.

Members of the Council may be re-elected.

If a member of the Council resigns during his term of office, the President shall immediately direct the election of a substitute by the members belonging to the country in question.

In the event of the death or resignation of the President, the Council will appoint one of its members to carry on the presidential duties till the next Congress.

The term of office of the Council lasts from one Congress till the next.

SEC. 9. The business of the Association will be attended to by the President, assisted by a paid Secretary.

The members of the Council will attend to the business of the Association in the country which they represent.

SEC. 10. The resolutions of the Congresses on technical questions merely serve to express the opinion of the majority. They are therefore in the form of recommendations and are in no way binding.

SEC. 11. The resolutions of the Congresses can only be carried if at least three-fourths of the recorded votes are in favor of them. Every member of the Association present, as well as every representative of official bodies and technical societies, has one vote.

The rights and duties of a member of the Association are not altered by the fact of his belonging at the same time to a national or other Association which Association is itself a member of the International Association.

SEC. 12. The technical problems to be considered by the Association will be decided upon by the Congresses and by the Council and will be duly referred to commissions or reporters appointed by the Council.

SEC. 13. The Council draws up its own regulations according to the By-Laws of the Association and to the needs which may from time to time present themselves.

SEC. 14. In the event of the Association being dissolved, any funds belonging to it will be handed over to the "International Red Cross Association."

THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

TECHNICAL PROBLEMS, COMMITTEES* AND REFEREES.

As constituted in August, 1905.

SECTION A.

METALS.

Problem 1.—On the basis of existing specifications, to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, A. Rieppel, Aeussere Cramer-Klettstrasse 12, Nuremburg, Germany.

Vice-Chairman, G. Alpherts, Koninginnegracht 66, Hague, Holland.

American Members, H. H. Campbell, James Christie, Carnegie Steel Company, represented by W. A. Bostwick; Franklin Institute, represented by A. E. Outerbridge, Jr., Paul Kreuzpointner, R. Moldenke, W. R. Webster, Walter Wood.

Problem 2.—To establish methods of inspection and testing for determining the uniformity of individual shipments of iron and steel. (Proposed at the Stockholm Congress, 1897.)

Committee:

Chairman, W. Ast, Nordbahnhof, Vienna, Austria.

Vice-Chairman (office vacant).

* The names of only the Chairmen, the Vice-Chairmen, and American Members of International Committees are here given.

American Members, Booth, Garrett and Blair, Thos. Gray, Gus. C. Henning, Paul Kreuzpointner, A. A. Stevenson, W. R. Webster, Albert Sauveur.

Problem 4.—Methods for testing welds and weldability. (Proposed at the Zurich Congress, 1895.)
Referee, R. Krohn, Danzig, Germany.

Problem 5.—Collection of data for establishing standard rules for piece tests, with special reference to axles, tires, springs, pipes, etc. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, W. Rayl, Nordbahnstrasse 50, Vienna, II, Austria.
Vice-Chairman, A. Sailler, Favoritenstrasse 20, Vienna, IV, Austria.
American Members, M. H. Wickhorst, H. V. Wille.

Problem 6.—On the most practical methods of polishing and etching for the macroscopic study of iron and steel. (Proposed at the Zurich Congress, 1895.)
Referee, E. Heyn, Carmerstrasse 15, Charlottenburg, Germany.

Problem 25.—To establish uniform methods of testing cast iron and finished castings. (Proposed at the Buda-Pesth Congress, 1901.)

Committee:

Chairman, R. Moldenke, Watchung, N. J.
American Members, Alex. E. Outerbridge, Jr., Albert Sauveur, Thos. D. West.

Problem 26.—Tests with notched bars for ascertaining the realtions between the different methods of testing and for fixing the numerical values representing the different properties of metals. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, Ed. Sauvage, Rue Eugène Flachat 14, Paris, France.

Problem 27.—Ball-pressure tests for ascertaining the relations between the different methods of testing and for fixing the numerical values representing the different properties of metals. (Proposed at the Buda-Pesth Congress, 1901.)

Referees, J. A. Brinell, Chief Engineer, Jernkontoret, Stockholm, Sweden; G. Dillner, Director Royal Laboratory for Testing Materials, Stockholm, Sweden.

Problem 28.—The consideration of the magnetic and electric properties of materials in connection with their mechanical testing. (Proposed at the Buda-Pesth Congress, 1901.)

Referees, K. Hochenegg, Techn. Hochshule, Karlsplatz, Vienna, IV, Austria; M. von Hoor Tempik, Kgl. techn. Hochschule, Buda-Pesth, Hungary.

Problem 36.—Macroscopic examination of iron. (Resolution of Council, 1903.)

Referee, W. Ast, Nordbahnstrasse 50, Vienna, Austria.

Problem 37.—Microscopic examination of iron. (Resolution of Council, 1903.)

Referee, F. Osmond, 83 Boulevard de Courcelles, Paris, France.

SECTION B.

NATURAL AND ARTIFICIAL BUILDING STONES AND THEIR CEMENTS.

Problem 7.—On the relation of chemical composition to the weathering qualities of building stones; the influence of smoke, especially sulphurous acid on building stones; the weathering qualities of roofing slates. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, A. Hanisch, Schellinggasse 13, Vienna, I, Austria.
Vice-Chairman, P. Larivière, Quai Jemmapes 170, Paris, France.
American Members, J. F. Kemp, Mansfield Merriman.

Problem 9.—On rapid methods for determining the strength of hydraulic cements. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, F. Berger, Rathhaus, Vienna, I, Austria.
Vice-Chairman (office vacant).
American Members, W. W. Maclay, Chas. McKenna.

Problem 10.—To digest and evaluate the resolutions of the conferences of 1884–1893 concerning the adhesive qualities of hydraulic cements.
Referee, R. Feret, Boulogne-sur-Mer, France.

Problem 11.—To establish methods for testing puzzolanas with the object of determining their value for mortars. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, G. Herfeldt, Andernach, Germany.
Vice-Chairman, C. Segré, Ancona, Italy.
American Members, A. Lundteigen.

Problem 12.—Investigation on the behavior of cements as to time of setting and on the best method for determining the beginning and the duration of the process of setting. (Proposed at the Zurich Congress, 1895; enlarged in conformity with the resolution of the Buda-Pesth Congress, 1901.)

Committee:

Chairman, E. Candlot, rue d'Edimbourg 18, Paris, France.
Vice-Chairman, N. Lamine, Zabalkansky 9, St. Petersburg, Russia.
American Members, Spencer B. Newberry, Clifford Richardson.

Problem 13.—On the normal consistency of cement mortars for test specimens. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, A. Greil, Rathhaus, Vienna, I, Austria.
Vice-Chairman (office vacant).
American Member, R. L. Humphrey.

Problem 29.—Determination of the liter weight of cement. The strength of neat hydraulic cements. Determination of a standard sand. (Proposed at the Buda-Pesth Congress, 1901.)
Referees, N. Belelubski, Rue Serpuchowskaja 4, St. Petersburg, Russia; F. Schuele, Eidg. Polytechnikum, Zurich, Switzerland.

Problem 30.—Determination of the simplest method for the separation of the finest particles in Portland cement by liquid and air processes. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, M. Gary, Kgl. mech.-techn. Materialprüfungsamt Charlottenburg, Germany.

Problem 31.—On the behavior of cements in sea water. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, H. Le Chatelier, Place du College de France 9, Paris, France.

Problem 32.—On accelerated tests of the constancy of volume of cements. (Proposed at the Zurich Congress, 1895.)

Committee:

Chairman, Bertram Blount, Broadway, Westminster, London, S. W., England.
Vice-Chairman (office vacant).
American Members, R. W. Lesley, Spencer B. Newberry.

Problem 33.—On the influence of the proportion of water and sand on the strength of Roman and other cements. (Proposed at the Buda-Pesth Congress, 1901.)
Referee, The Hungarian Society for Testing Materials, Buda-Pesth, Hungary.

SECTION C.

OTHER MATERIALS.

Problem 17.—On methods of testing tile pipes. (Proposed at the Stockholm Congress, 1897.)

Referee, M. Gary, Kgl. Materialprüfungsamt Charlottenburg, Germany.

Problem 18.—On the methods of testing the protective power of paints used on metallic structures. (Proposed at the Zurich Congress, 1895.)

Referees, Albert Grittner, Kobanyai ut 30, Buda-Pesth, Hungary; E. Ebert, Centralbahnhof, Munich, Germany.

Problem 19.—On uniform methods for testing lubricants. (Proposed at the Zurich Congress, 1895.)

Referee, N. Petroff, Zagorodny 70, St. Petersburg, Russia.

Problem 23.—On uniform methods for compression tests of wood.

Committee:

Chairman, Prof. A. Schwappach, Eberswalde, Germany.
Vice-Chairman, A. Wykander, Goeteborg, Sweden.
American Member, Filibert Roth.

Problem 35.—Study of the methods of testing caoutchouc. (Proposed at the Buda-Pesth Congress, 1901.)

Committee:

Chairman, E. Camerman, Rue Philippe Le Bon 73, Brussels, Belgium.
Vice-Chairman (office vacant).
American Member, R. G. Pearson.

SECTION D.

MISCELLANEOUS SUBJECTS.

Problem 22.—Considering that the resolutions formed by the International Conferences of Munich, Dresden, Berlin, Vienna and Zurich, for the purpose of attaining unity in the methods of testing materials, and the report of the Committee of the American Society of Mechanical Engineers do not agree in many points with the decisions arrived at by the French commission, it is proposed that the Council appoint a commission which shall prepare a report upon these differences, and proposal for ways and means of abolishing them.

Committee:

Chairman, N. Belelubski, Rue Serpouchowskaya 4, St. Petersburg, Russia.

Vice-Chairmen, A. Martens, Kgl. Materialprüfungsamt, Charlottenburg, Germany; E. Sauvage, l'Ecole des Mines, Paris, France.

American Members, Albert Ladd Colby, Gus. C. Henning, R. Moldenke, George F. Swain, George S. Webster, W. R. Webster, Walter Wood.

Problem 24.—On uniform nomenclature of iron and steel. (Resolution of Council, February 3, 1901.)

Committee:

Chairman, H. M. Howe, 27 West Seventy-third street, New York. N. Y.

Vice-Chairmen, L. Lévy, Rue de La Rochefoucauld 19, Paris, France; D. Tschernoff, Rue Pessatschenaia 25, St. Petersburg, Russia.

Secretary, Albert Sauveur, 446 Tremont street, Boston, Mass.

American Member, H. H. Campbell.

Problem 34.—Fixing a uniform definition and nomenclature of the bitumens. (Proposed at the Buda-Pesth Congress, 1901.)

Committee:

Chairman, G. Lunge, Eidg. Polytechnikum, Zurich, Switzerland.
Vice-Chairman, Jenoe Kovacs, Tataros (Post Mezoe Telegd), Hungary.
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